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## Monterey, California



## THESIS

### INTERNETWORKING: MULTICAST AND ATM NETWORK PREREQUISITES FOR DISTANCE LEARNING

by

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September 1996

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# **INTERNETWORKING: MULTICAST AND ATM NETWORK PREREQUISITES FOR DISTANCE LEARNING**

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## ABSTRACT

The Internet, the World Wide Web and the Multicast Backbone (MBone) have been used in a variety of ways for distance learning. Video TeleConferencing (VTC) classrooms have obvious value and utility but they are limited to communicate with only a small number of similar VTC facilities. We are most interested in open solutions which take advantage of the global Internet. Therefore the problem addressed by this thesis is to evaluate the specific benefits and drawbacks of Internet technologies in support of distance learning.

This thesis includes a detailed examination of MBone, Asynchronous Transfer Mode (ATM) and the Distributed Interactive Simulation (DIS) protocol from the perspective of distance learning. An innovative design for a low-cost Web/MBone-capable classroom is presented. Experimental results include globally multicasting the IEEE Autonomous Underwater Vehicle (AUV 96) conference and digitally recording the 1996 Monterey Bay Web Content and Access Workshop.

One result we found is that MBone can be used successfully for distance learning purposes despite common constraints of limited (128 Kbps) bandwidth. A further result is that an MBone classroom can be 42% as expensive as a VTC classroom if an *SGI Indy* is used and 12% as expensive as a VTC classroom if a PC is used in the classroom. Consequently many schools can afford Internet-based distance learning using the solutions presented in this thesis even though they cannot afford VTC rooms.



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# **I. INTERNET-BASED DISTANCE LEARNING**

## **A. INTRODUCTION**

This thesis explores ways of creating distance learning environments using the Internet. Utilizing the Internet includes local-area, regional and global networks connected to the Multicast Backbone (MBone) and Asynchronous Transfer Mode (ATM) to augment standard Internet connectivity with high-bandwidth, low-latency links. Distance learning is a relatively new topic related to video conferencing. Since video conferencing has tight limits on the number of people who can participate and is expensive to install and maintain, the idea of adapting Internet-based video conferencing for distance learning is appealing.

ATM is a new technology that is being investigated by many researchers. The major features of ATM that are important to distance learning are high bandwidth and low latency. These two features allow full-motion video, real-time audio, and interactive 3D applications at faster rates than is ordinarily possible using standard Internet links.

Each topic mentioned above is quite broad. This thesis examines each from the narrow perspective of Internet-based distance learning. Related work includes establishing an ATM Local-Area-Network (LAN) at the Naval Postgraduate School (NPS) and connecting to the Monterey Bay ATM Network (Monterey BAYNET ATM). Related work also includes examining the testbeds in the U.S. such as Bay Area Gigabit Testbed Network (BAGNET), The International Wide-Area Year (I-WAY) project and examining an exemplar application, the Chesapeake Bay Virtual Ecosystem Model (CBVE). Furthermore a series of experiments to create an internetworked distance learning classroom and to support distance learning at off-site and on-site locations are performed.

The basic motivation for this thesis remains using the existing Internet for distance learning. This thesis combines knowledge and experiments together in order to provide a good starting point, practical examples and a reference for successors in the same area of research.

## **B. BACKGROUND**

Studies on the MBone started in 1992. Today MBone tools are available for almost all platforms including PC's. Tools for the Macs are expected to be ported soon. The first use of MBone at NPS was achieved in 1993 by Mike Macedonia and Don Brutzman to test the NPSNET real-time virtual environment simulation program over the Internet [Macedonia 95].

Tracey Emswiler used MBone tools to multicast Dr. Richard Hamming's course "Future of Science and Engineering: Learning to Learn" in real time over the global Internet during an entire quarter [Emswiler 95]. This was the first full academic course multicast globally. MBone has often been used for multicasting special events, conferences and lectures. Nevertheless MBone has not been used much for distance learning, since the aggregate global bandwidth for MBone is limited (500 Kbps) and there are not many MBone connections around the world (approximately 2800 LANs). The number of MBone users continues to increase slowly but exponentially. Any site with adequate bandwidth (typically T1, 1.5 Mbps or better) can connect. Multicast connectivity will continue to improve since native multicast support is built into the next-generation Internet Protocol (IPv6).

Studying today's technology encourages us to think about the future. Video, audio, 3D graphics and other applications may work fine within the limitations of the Internet for

now, but the increasing demand will force the use of faster technologies. There are currently no “real” full-motion video, audio and 3D applications. Many competing demands must be considered. For example, the process of compression/decompression conserves bandwidth but also increases latency. Interactive 3D graphics applications may have lower bandwidth demands than video but higher throughput in terms of packets per second. Thus any experiments and any conclusions must include many considerations.

### **C. MOTIVATION**

Widely distributing an application, whether or not the application is very valuable and useful, is mostly dependent upon economics. For the purpose of this thesis, the author chose to follow a method of doing things that is affordable.

Proprietary commercial video teleconferencing is an expensive application to install and maintain in secondary public schools. Video conferencing requires modified classrooms, special equipment, and dedicated connections. However MBone classrooms are less of an investment since they use the Internet. Free MBone software tools are available for most computers. Ordinary and inexpensive video cameras and display monitors can usually be provided at any location. This type of equipment does not require trained personnel to build, maintain, or operate. Thus open Internet-based solutions are appealing. This thesis demonstrates working solutions for distance learning using MBone.

Another motivation for this thesis is to give conditions and steps to multicast lectures with the least effort and money. Augmenting a conference or lecture hall with MBone capability is not prohibitively costly. Connecting classrooms now appears feasible and straightforward.

Another motivation in this thesis is to explore distance learning using ATM.

Unfortunately significant problems with ATM precluded such a study. Our long-term goals include building large-scale virtual environments (LSVEs) using ATM links and the existing Internet, by using the Virtual Reality Modeling Language (VRML) and developing a virtual reality transfer protocol (vrtp) [Brutzman 96].

## **D. THESIS ORGANIZATION**

Following this introduction, the related work chapter examines previous and current works related to this thesis. The problem statement chapter explains the main problems that are taken as the reason for this research. The subsequent chapter documents the idea of MBone and its use at NPS. The ATM chapter summarizes ATM concepts for readers to let them understand how ATM relates to distance learning. The DIS chapter does the same thing for DIS by emphasizing use of DIS with MBone for distance learning. The experimental results chapter examines three major experiments performing during this research and evaluates their results. The experiments are building an MBone/Web classroom, multicasting the AUV 96 conference globally through the Internet by using MBone, and digitally recording the Monterey Bay Web content and access workshop with MBone software tools. The conclusions and recommendations chapter has both the results of the thesis and recommendations for the future work. Following the chapters, the first appendix explains how to connect computers to a new network. The second appendix is a kind of starter kit for MBone that gives the Internet sites for downloading MBone software and getting information about MBone. The subsequent appendix has abbreviations and definitions used in the thesis. Appendix D gives the on-line retrieval information for this thesis. The following two appendices document details for building and running an MBone/Web classroom, as well as planning and managing the AUV 96 conference

multicast. The last appendix documents the current price comparison between video teleconferencing (VTC) and MBone classroom.





## II. RELATED WORK

### A. INTRODUCTION

This chapter discusses related work within a context of what needs to be considered when using the Internet and MBone for distance learning. This chapter also includes related work on Asynchronous Transfer Mode (ATM) usage for the purpose of distance learning.

There are few examples of using MBone for distance learning in the same way as presented in this study. Summaries in this chapter include previous and current work on MBone and distance learning.

### B. PREVIOUS WORK

1. *An Analysis of Internet's MBone: A Media Choice Perspective*: [Gambrino 94]- This master's thesis examines the effectiveness of Internet's Multicast Backbone (MBone) compressed-motion video-teleconferencing system (*vat* and *nv* circa 1994) and analyzes its capabilities and limitations. The analysis follows the media richness model of media choice and discusses seven influences on a manager's media selection. This study focuses on human-factors considerations of distance learning using compressed-motion video-teleconferencing.

2. *Desktop Videoconferencing: Technology and Use for Remote Seminar Delivery*: [Rettinger 95]- A master's thesis that investigates the current state of desktop videoconferencing technology and evaluates the potential effectiveness of this technology for delivering interactive seminars to a remote audience. All aspects of desktop video conferencing are discussed in this study. A weekly seminar class was multicast using the

Internet MBone to demonstrate the use of desktop video conferencing for distance learning.

3. *Using the Multicast Backbone (MBone) for Distance Learning:* [Emswiler 95]-

A master's thesis that documents the viability and impact of distance learning using the MBone. The case study documents the learning points derived from the successful world-wide multicast of the Dr. Richard Hamming course "Learning to Learn." The research provided complete course coverage, world-wide, for a full academic quarter. This is the first documented attempt of extending traditional education methods using the MBone.

4. *Internetworking: Planning and Implementing a Wide-Area Network (WAN) for K-12 Schools:* [Bigelow 95]- A master's thesis documenting the design of a regional network, Monterey BayNet. Monterey BayNet is the network that connects kindergarten through twelfth grade (K-12) students, educators and research institutions throughout Monterey and Santa Cruz counties on the central California coast. This case study was the first step toward a networked approach for distance learning in Monterey Bay area.

5. Bay Area Gigabit Testbed (BAGNET)- Fourteen organizations within the San Francisco Bay Area formed a gigabit testbed to develop and deploy the computer multimedia network infrastructure needed to support a diverse set of distributed applications in a large scale, metropolitan ATM network environment. In this project, ATM technology is used in large-scale teleseminars, distributed storage and on-line multimedia libraries in order to show the capabilities of a future Internet. The BAGNET home page has the information about the work in detail [BAGNET 95].

6. Monterey Bay ATM Network (BAYNET) - Pacific Bell awarded two years' free usage of the company's ATM service to regional testbed consortia under the CalREN

(California Research and Education Network) program. The Monterey Baynet ATM connectivity was funded by CalREN program. Attempted applications in BAYNET include distance learning between UCSC (University of California, Santa Cruz) and UC Extension, and also distance learning between Monterey Bay Aquarium (MBA), Monterey Bay Aquarium Research Institute (MBARI) using the Bay Link application which provides a live video link between MBA/MBARI and San Jose Tech Museum of Innovation (SJTMI).

7. NPS Network Simulator (NPSNET)- The NPSNET networked virtual environment, developed at the Computer Science Department of the Naval Postgraduate School (NPS) in Monterey, California was the first distributed virtual environment simulation that was played over the global Internet using MBone-compatible Distributed Interactive Simulation (DIS) protocol [Macedonia 95]. This work is especially important since it demonstrates a new class of applications for the Internet. Distributed 3D real-time environments are also important for the future of distance learning.

8. Remote Seminars through Multimedia Conferencing: Experiences from the MICE project [Sasse 94]- The aim of the MICE (Multimedia Integrated Conferencing for Europe) project is to enable useful internetworking between European researchers via multimedia conferencing technology.

## **C. CURRENT WORK**

1. Multimedia European Research Conferencing Integration (MERCI) [MERCI]- The goal of this project is to pilot interworking between European researchers and also to connect to sites in the U.S. using existing facilities. This project is a successor to Multimedia Integrated Conferencing for European Researchers (MICE) (which ended in

September 1995) with additional emphasis on the integration of individual software tools and their porting to diverse platforms and networks. The MERCI system currently allows multimedia conferencing (audio, video, and shared workspace) between conference rooms and workstation-based facilities, hardware and software codecs, packet-switched networks and ISDN, using both unicast and multicast technology.

2. *Internetworking: NPS ATM LAN*: [Courtney 96]- A master's thesis that documents the installation of ATM technology at NPS. The objective of this case study is to create, test, and build an ATM network to support real-time tele-education and digital interactive multimedia. This case study was intended to be one foundation for this thesis, experimenting with ATM capabilities, and building an ATM backbone for future use in distance learning and other high bandwidth low-latency, multicast applications. However, the research concluded that ATM is currently a failure, due to the following reasons:

- There is an interoperability problem among the ATM switches.
- ATM is currently incompatible with IP multicast.
- Long-haul setup is a time consuming process and the fees for the links are prohibitively expensive.
- People that really understands ATM networks are few. Therefore there is a human engineering problem.
- There is a crossover problem. When one connection is broken then there is no alternative connection to carry on the link.

3. *Internetworking: Implementation of Multicast and MBone Over Frame Relay Network*: [Erdogan 96]- A master's thesis that documents the implementation of MBone over Monterey BayNet for educational purposes. It documents the requirements for re-configuration of Monterey BayNet sites to join MBone. It shows that MBone over Frame Relay networks is possible and the current MBone technology provides excellent performance even on low-speed network connections. This thesis is especially helpful to

show how to configure and use MBone in networks which may possibly be used by the schools for distance learning purposes.

4. The Chesapeake Bay Virtual Ecosystem (CBVE) Model- This model incorporates linked submodels of various organic and inorganic substances with various oceanographic processes all of which will be spatially and temporally linked via three-dimensional Chesapeake Bay circulation model [Wheless 96]. Future goals include integrating this project completely with the Web, and showing the functionality of using the Internet to import or export any type of media, including the generation of 3D graphics object models compatible with the Virtual Reality Modeling Language (VRML) [Carey 96].

5. *Internetworking: Economical Storage and Retrieval of Digital Audio and Video for Distance Learning*: [Tiddy 96]- A master's thesis that documents the testing and comparison of currently available methods of digital audio and video storage and the use of current transfer modes and protocols for on-demand retrieval over the Internet. This case study is relevant to this thesis by demonstrating digital storage of distance learning recordings for later retrieval over the Internet.

## **D. SUMMARY**

In this chapter, related work concerning MBone and ATM in distance learning are summarized. One section consists of previous work and the other consists of current work. Studies that involve distance learning were not found, presumably due to the newness of ATM technology.



### **III. PROBLEM STATEMENT**

#### **A. INTRODUCTION**

This chapter defines and explains the problems of the thesis. Methodology, expected solutions to the problems encountered and success criteria are also described.

#### **B. PROBLEM AND METHODOLOGY**

The Internet, the World Wide Web and the Multicast Backbone (MBone) have been used in a variety of ways for distance learning. However, it is not clear how practical they are as an affordable alternative to proprietary commercial video-conferencing systems. Video TeleConferencing (VTC) classrooms have obvious value and utility, but they are limited to communication with only a small number of similar VTC facilities. This study is interested in open solutions which take advantage of the global Internet. Therefore, the problem addressed by this thesis is to determine various benefits and drawbacks of Internet technologies in support of distance learning.

Specific goals include use of the Internet and the MBone for distance learning purposes, and to demonstrate the feasibility of a Web/MBone classroom by building it. Additionally, the classroom needs to be affordable so that schools which do not have large budgets may participate in global distance learning. The ultimate Web/MBone classroom must be both simple and affordable. By simple, we mean that it can be built, used and maintained by anybody (students or instructors) with no special training on the system. The classrooms should make use of all facilities of the Internet such as Web pages, global multicast of audio/video.

MBone tools have been used experimentally on several occasions throughout the world in the last few years. Our plan was to experiment with MBone in a systematic way

by increasing capacity within a changing environment. Success is defined as building and running an affordable Web/MBone classroom, experimenting with MBone for larger functions like workshops or conferences, and evaluating the results of these experiments for future researchers. The major point of this evaluation is to be able to recommend to other educational organizations how to use MBone for distance learning. We provide a reference for building, running and maintaining Web/MBone classrooms to assist others in participating in global distance learning. We also examine the suitability of Asynchronous Transfer Mode (ATM) networking for high-bandwidth distance learning, and the Distributed Interactive Simulation (DIS) protocol for large-scale virtual environments (LSVEs).

The first step in reaching these goals is to build a Web/MBone classroom using inexpensive, available equipment. In this case, the equipment was borrowed from different departments in the school. Evaluation of these results shows that MBone can be used for distance learning comfortably and effectively.

After evaluation of classroom environment, the Web/MBone classroom equipment is used and evaluated in other environments to learn about other Internet-based distance learning opportunities. Subsequent steps in this evaluation include multicasting a large conference globally, and multicasting a small workshop from an auditorium to test digital recording. Digital recording is another important issue for the storage of Internet distance learning. The auditorium experiment gave practical experience on storing MBone sessions digitally and moving them through Internet when necessary.



## **C. SUMMARY**

The problem examined in this thesis is to evaluate the specific benefits and drawbacks of Internet technologies in support of distance learning. Open solutions which take advantage of the global Internet are the main interest. Goals are to include use of the Internet and the MBone for distance learning and to demonstrate the feasibility of a Web/MBone classroom as well as the low cost. Success is having a working, affordable Web/MBone classroom and showing the usage of MBone for distance learning purposes.



## **IV. MBONE AT NPS**

### **A. INTRODUCTION**

This chapter documents recent Multicast Backbone (MBone)-related work at NPS.

The first section gives background information on the experiments at NPS. The second section presents the ideas behind the design of a MBone/Web classroom, as well as the pros and cons of using MBone in a distance learning classroom, a lecture hall, and a conference. The requirements for each kind of event are presented in detail, including directions on how to connect to MBone. The concluding section presents some ideas on achieving distance learning at NPS or in any other organization.

### **B. BACKGROUND**

The MBone was named by Steve Casner and has been around since early 1992 [Casner 92]. The MBone is a virtual network that is layered on top of portions of the physical Internet to support routing of IP multicast packets. Because multicast connectivity has not yet been integrated into some production routers unicast tunnels are sometimes used to pass multicast. Most vendors have provided native IP multicast into their recent routers.

Multicast (unlike unicast or broadcast) supports selectable one-to-many and many-to-many connections over the Internet. Class D Internet addresses (which have a first-byte value between 224 and 239) are reserved for IP multicasting.

On the Internet, there are link layer technologies that naturally support multicast (such as Ethernet and FDDI). These subnets are linked by virtual point-to-point links called "tunnels" since some regular IP routers do not support multicast. At the endpoints

of a tunnel, there are multicast routers (mrouters) that encapsulate the multicast packets within an IP header and then send them through the tunnel. The receiving side is also an mrouter. It removes the IP header and deliver the packet to its group address. Mrouters are usually workstation-class machines having operating system support for IP multicast and running the public-domain “mrouted” multicast routing daemon.

NPS has been working with the MBone for several years. Dr. Richard Hamming’s “The Art of Science and Engineering: Learning to Learn” course was multicast using the Internet by using MBone tools called Network Video (*nv*) for video and Visual Audio Tool (*vat*) for audio in Spring 1995 [Emswiler 95]. This experiment proved that the MBone is a viable asset for distance learning.

Studies so far have merely shown that the MBone can be feasibly used for video/audio transmission in a multicast environment. This thesis examines ways that distance learning might use MBone easily and effectively on a regular basis.

In recent years there has been a large emphasis (and expenditure of funds) on Video Tele Conferencing (VTC). Significant drawbacks exist with this approach (Figure 4.1).

- **VTC is expensive (special purpose equipment, connections, etc.)**
- **VTC equipment is not completely standardized yet**
- **VTC needs specially trained personnel to operate and maintain it**
- **VTC is capable of few simultaneous connections (maximum 7 to 10)**

Figure 4.1. Some drawbacks of VTC.

In comparison, using the existing Internet and MBone anywhere in the world costs almost nothing, is easy to install, is easy to use and maintain, and has the capability of

connecting numerous sites simultaneously. These are important reasons for choosing MBone instead of VTC for distance learning purposes. We therefore look at these issues in detail.

### **C. MBONE/WEB CLASSROOM DESIGN**

The Internet is an undeniably good reference source. On the Internet, the World Wide Web (Web or WWW) allows for new dimensions in communication and vision. Any individual or institution can have a home page on the Internet. That has increased the usage of the Internet for reference. Search engines made information easy to find. Static slides can be replaced with projections of the relevant home page screens in lectures and conferences. Addition of the MBone allows users to include interactive audio and video during a lecture or a conference. Therefore the idea of combining web browsing and the MBone in a lecture is a good idea for distance learning experiment. The lecture can be transmitted to several sites through MBone, and participants at either the near or far end can follow the instructor with MBone tools and Web browsers (Figure 4.2).

These ideas are the main motivation for a MBone/Web classroom. Potential benefits are summarized in Figure 4.3 and potential drawbacks are in Figure 4.4.

### **D. LECTURE HALL CONFIGURATION**

Lecture halls are different than ordinary classrooms. First of all, a lecture hall may accommodate 100 people or more, whereas a classroom may be made up of only 25-30 people. This difference makes lecture hall configuration more difficult, because audio and video quality are more important for larger spaces. These factors must be taken into account when a lecture hall is configured for an MBone session such as a conference.

Microphones and camera(s) must be placed in the hall very carefully.

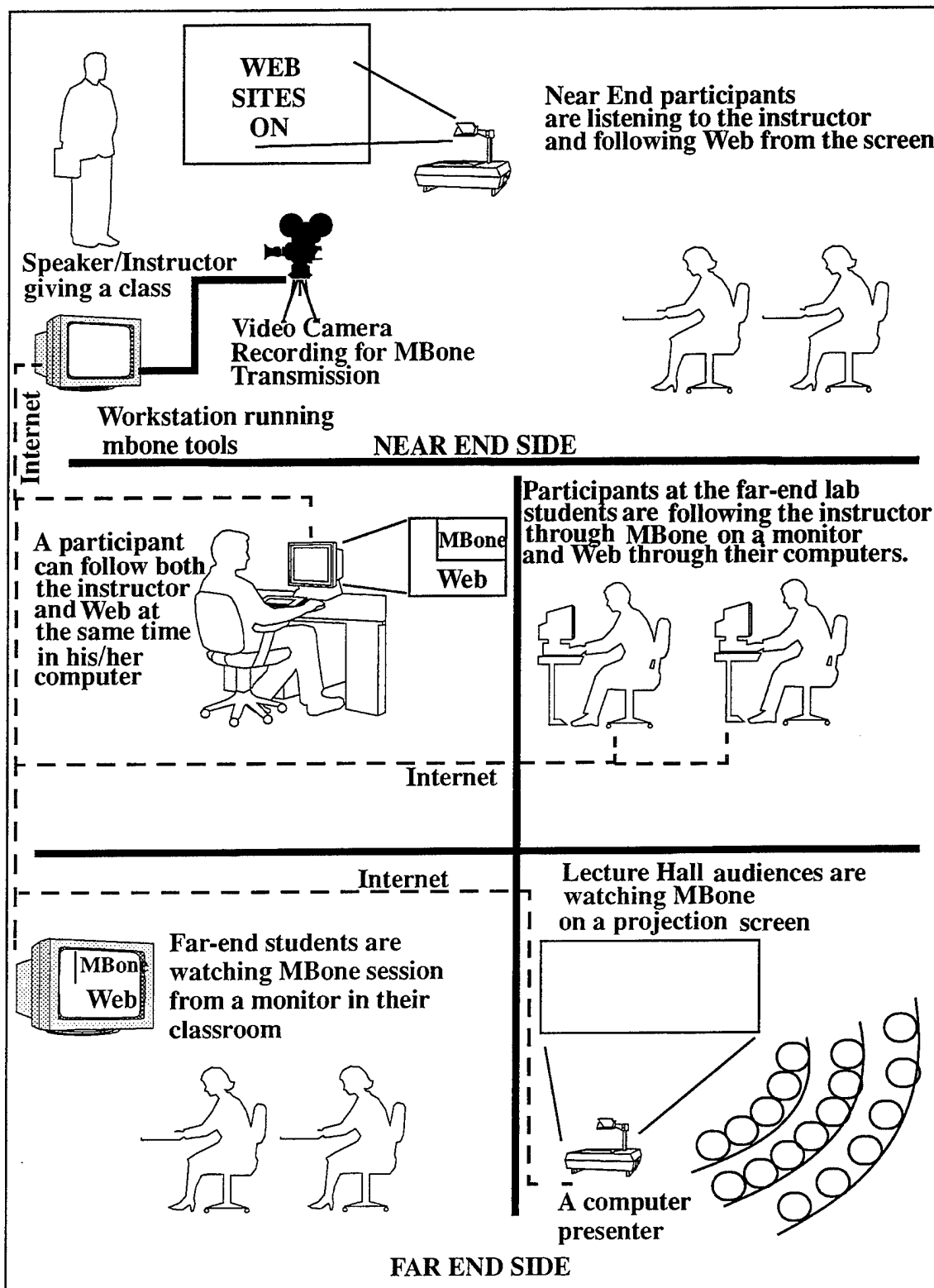


Figure 4.2 Example Use of MBone in Distance Learning

- **Building an MBone/Web class is much cheaper than building a video conference room. More specifically, the equipment used in MBone is ordinary equipment and consequently easier to find and purchase (or borrow), and you do not need to pay extra money for the connection as in case of video conferencing.**
- **It is easy to use the room and it does not have to adhere to a strict schedule.**
- **Since the system accepts any kind of computers and any kind of connections, it is easier to distribute through out any school.**
- **A lecture or a conference can be sent and received by all MBone-capable networks around the world simultaneously.**

Figure 4.3. Benefits of Web/MBone classrooms for the schools.

- **Video conferencing rooms are usually separate and secured rooms, but MBone/Web classrooms are ordinary rooms so that they are not necessarily secured. As a result, equipment used in the classroom needs to be secured.**
- **Since everybody can use the rooms for his/her own purposes, it is a little bit difficult to maintain the rooms, and follow the activities of people using the rooms. It is not necessarily a requirement to use MBone or Web for scheduling a class in that particular room.**
- **Since the equipment used may be borrowed from a system administrator from another department, equipment can go back and forth for reasons not related to MBone.**

Figure 4.4. Some Disadvantages of Web/MBone Classrooms.

Another factor is that the quality of the audio equipment used in lecture halls may need to be higher than that used in classrooms, because the noise in the lecture hall created by a larger number people must not be multicast. The best thing that can be done is to use

built-in house audio (public address system), if available for this purpose, and connect it to the computer system.

Since lecture halls are usually open for public use in schools, assigning dedicated computer, audio and video systems to the halls is almost impossible. The problem with computers that are not permanently assigned is that they may need to be reconfigured each time they are moved to the lecture hall. Configuration of host numbers and network services is usually a painful operation for system administrators.

MBone/Web lecture halls can save money just like classrooms. Instead of paying a nearby hotel for holding a conference or a lecture, using their own assets at the school with zero cost is attractive to many administrators. The security of equipment issue is also present in lecture halls. It is difficult to secure a lecture hall that sees regular public use.

## **E. REMOTE CONFERENCE MULTICAST SUPPORT**

One important event in which the MBone was used was Autonomous Underwater Vehicle (AUV) 96 Conference held by NPS at the Hyatt Regency Hotel in Monterey between 2-6 June 1996. The three-day conference was multicast globally. According to remote and local attendees, the conference was a worthwhile achievement with individuals watching the conference on their computers in different places around the world. On the first day the video and audio quality was occasionally poor, but after students became more experienced with the MBone tools and video cameras quality improved day-by-day.

Since there was no convenient room for that size conference in the school, all the MBone-related equipment had to be taken to the conference location. The biggest problem was a lack of network connections in the hotel. Thus a network had to be constructed. From previous experiments, we had known that the easiest way to provide a network



connection was to use an Airlan bridge. This equipment is a wireless bridge connected to a MBone-capable subnet at the school. One connection is a main unit with an antenna at the school, and another wireless bridge at the hotel with its antenna directed back to the school acts as a repeater between the hotel and the school. Details about the topology and configuration may be found in Chapter VII.

Before taking the assigned computers to the conference, they need to be configured for the subnet that they will be assigned. MBone tools and other programs need to be installed locally since the normal network file system (NFS) will not be available. Configuring computers for a different subnet is explained in detail in Appendix A.

After moving the necessary gear to the conference hall, every item must be tested as if the conference has begun. Even though the equipment initially seems to be working, a system administrator must be present to help with inevitable problems. Most of the time problems are related to the system configuration, and only a system administrator with root permissions can fix those sort of problems.

## **F. MODIFYING MBONE TOPOLOGIES**

Connecting to MBone or connecting to an MBone capable networks has been mentioned several times. In this section, connecting to MBone will be explained. Before explaining the necessary steps to join the MBone, it is probably better to define a few terms that will be used in the remainder of the chapter.

*Tunnel:* A tunnel is a point-to-point connection between two multicast capable routers. Since the Internet uses IP unicast transmission mode, routers have to send their packets in IP unicast. They can not recognize the multicast D-type IP addresses. So the multicast router that wants to send a multicast packet across an IP network will use this

point-to-point tunnel connection prepend another IP header, and set the destination address in the new header to be the unicast address of the multicast router at the other end of the tunnel.

*mrrouter/mrouted*: End points of a tunnel are called multicast routers (mrouters). They are in charge of distributing and replicating the multicast data streams to their destinations [Kumar 96]. They are usually regular workstations that run a multicast route daemon, (*mrouted*) to behave as an mrouter. Recently most new IP router products have begun to support multicasting.

*MOSPF, DVMRP*: The Multicast Extensions to Open Shortest Path First (MOSPF) is defined in RFC-1584. Distance Vector Multicast Routing Protocol (DVMRP) is defined in RFC-1075. They are two different kinds of multicast routing protocols that are used by mrouters to build effective routing trees to transmit multicast packets to their targets.

The procedure to join the MBone follows [Macedonia 95]. First, your network provider must be on the MBone. Otherwise you should create a tunnel to a network provider near you. This is not recommended since it may overload links with duplicate tunnels to separate end nodes. If you are a network provider, send e-mail to the request address of the mailing list for your country to be added to that list for the purposes of coordinating, setup of tunnels, etc. The list of e-mail addresses is in Appendix B.

Second, you should assign a Unix workstation to be the mrouter. Download *mrouted* from one of the sites listed in Appendix B in the Internet and install it on the mrouter. Change the */etc/mrouted.conf* file according to your requirements. This is usually done to create a tunnel between you and a site on the MBone. Build a kernel with IP multicast extension added in your workstation (if it is not already built-in) and then install

the kernel.

Lastly, send an e-mail to your Internet service provider or the MBone list in your region asking to hook in. In this e-mail you will include "Request for tunnel" as the subject, and then write your endpoint configuration information. After you receive confirmation, you may need to make small changes in your `/etc/mrouted.conf` file to include the MBone provider's tunnel information. After that, start the `mrouted` daemon [Kumar 96]. You test your MBone tunnel by running the MBone tools, such as *sdr* and *sd*. More information about each step can be found at the addresses in Appendix B.

## **G. REGARDING MBONE AND DISTANCE LEARNING**

Success in using the MBone for distance learning can be achieved with a little funding for equipment used in MBone, and by encouraging people to experiment on MBone. Some of the necessary conditions to achieve MBone distance learning are shown in Figure 4.5.

## **H. SUMMARY**

This chapter documents the use of MBone for distance learning at NPS. This information includes setting up an MBone/Web classroom, configuring a lecture hall, providing multicast support to a conference, and connecting to the MBone. The last section lists some "must do" requirements to be successful in using different aspects of MBone for distance learning purposes.

- **Deploy the equipment in the MBone classroom permanently. Do not let other users change the configuration.**
- **After setting up the classroom and reaching the goal, replace all the borrowed gear with permanent equipment.**
- **Carefully record configuration for the classrooms and lecture halls in your school, in order to rebuild them if necessary.**
- **Learn how to configure the computers, since it is not always possible to find a system administrator.**
- **MBone documents, programs and routers must frequently be updated to gain better performance. Configurations and other information on the experiments are covered in Chapter VII.**

Figure 4.5. Some Necessary Conditions to Achieve MBone Distance Learning.

## **V. ATM MBONE-COMPATIBLE DISTANCE LEARNING**

### **A. INTRODUCTION**

This chapter examines the potential use of ATM for distance learning. In the “Background” section readers can find information on three generations of networking and communications history. The “Information about ATM” section describes moving data from one host to another using ATM, packaging data into cells through the ATM layers, and the transmission media used for ATM. In the “Internet Protocol (IP) Compatibility with ATM” section the author explains how unicast IP works over ATM and recent progress in that area of the technology. The “Integrating multicast and MBone with ATM” section deals with one of the primary themes of thesis, which is distance learning using MBone over ATM. This section also examines a major problem with ATM: inability to support many-to-many IP multicast. The last three sections describe arranging long-haul ATM connections, ATM-related work at NPS, and a report on the Bay Area Gigabit NETwork (BAGNET).

It must be noted that original expectations for this chapter included experimental use of ATM to support distance learning. Unfortunately ATM problems encountered in this and a related thesis [Courtney 96] prevented accomplishing meaningful experimental results. Nevertheless this chapter provides a good basis for continued efforts to utilize ATM for MBone-compatible distance learning.

### **B. BACKGROUND**

According to Sterbenz, the history of networking and communications can be divided into three generations [Sterbenz 95]. The first generation, which is principally characterized by voice communication, entertainment, and data networking, ended in the

1970's. Voice communication was achieved using analog systems. Entertainment was broadcast of radio and television. Data communications was provided by connecting terminals to a host (by serial link for short distances, or by modem for long distances).

In 1980's second-generation networking introduced the Internet. The internal telephone network switches and trunks became digital for most connections. PBXs (Private Branch eXchange telephone switches) and mobile communications (cellular telephone systems) became available. In the entertainment category, cable networks, BBS (bulletin board systems) and on-line services (such as America On Line, Compuserve, and Prodigy) became utilized in daily life. In data networking, remote login and electronic mail were utilized while workstations and PCs were networked using Ethernet and token rings. For the first time connection-oriented networks using protocols like BNA, DECNET and SNA became available. Because the differences between protocols and network architectures were incompatible, most networks were poorly interconnected.

In the third (and current) generation, the voice, entertainment and data networking categories are merging. Multimedia communication (data, voice, and video) runs over fast cell-switched and routed networks in LANs and WANs.

Increasing demand for high bandwidth and low delay over long distances has lead researchers to develop several high-speed network technologies offering data rates of hundreds of Mbps, such as FDDI, Frame Relay, Fast Ethernet, Ether switch, and most recently Asynchronous Transfer Mode (ATM) [Kavak 95].

Among these techniques, ATM has generated the most interest due to its apparent flexibility and support of multimedia traffic. ATM is well suited to meet most requirements for high-speed networking.

## C. INFORMATION ABOUT ATM

The basic purpose of ATM is to provide a high-speed low-latency switching network to support various types of traffic such as data, voice and video. In order to achieve this goal ATM segments and multiplexes user traffic into 53 byte-segments called “cells” (Figure 5.1) [Black 95].

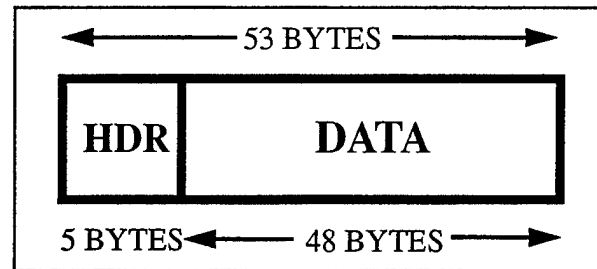


Figure 5.1 53-byte ATM Cell

The first five bytes are called the “cell header” and are used by User-to-Network Interfaces (UNIs), Network-to-Network Interfaces (NNIs) and switches to route the cell. The data part of 48 bytes may include additional overhead bytes as well as data [Partridge 95].

There are two distinct forms in UNI, described in [The ATM Forum 95]. *Public UNI* interconnects an ATM user with an ATM switch in a public service provider’s network. *Private UNI* interconnects an ATM user with an ATM switch in the same corporate network. Both UNIs share the ATM layer specification but they may use different physical media. Public UNI facilities used in connections between users and switches must be capable of spanning long distances, whereas in private UNI the switching equipment is located a limited distance from the user device. A possible ATM topology using both public and private UNI is shown in Figure 5.2. The UNI cell header

format is shown in Figure 5.3.

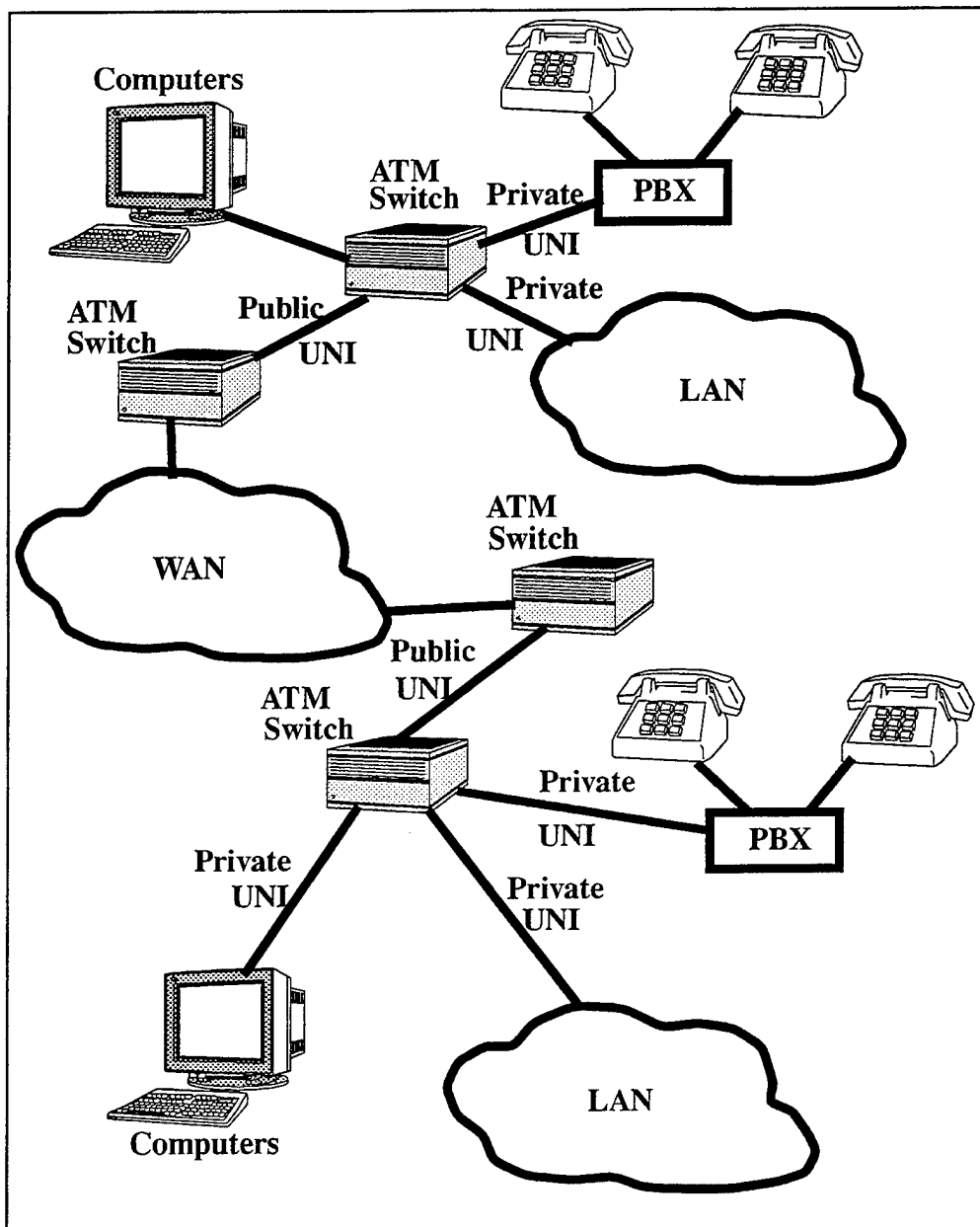


Figure 5.2 An ATM Topology Using both Public and Private UNI. After [Black 95]

NNI is utilized to provide smooth connections between independently operated ATM networks. Since the purpose of NNI is different than UNI, its cell header format is slightly different than UNI. In the NNI cell header format described in Figure 5.4, 12-bit Virtual Path Identifier (VPI) and 16-bit Virtual Circuit Identifier (VCI) are the first two fields. VPI and VCI together form a unique, 28-bit address for an ATM connection. As an



example and to explain how VPI and VCI are used, suppose that every ATM cell header is a telephone number that covers both VPI and VCI fields. In general, a telephone number has an area code and a local number, such as (408) 372-4720. In this example 408 is the area code and 372-4720 is the local number. When VPI is replaced with the area code and VCI with the local number, that combined information provides the switches with the connection between two end-points. First switches look at the VPI to determine if the number is local or not. If the number is local, the switch then looks at the VCI number and sends it to the destination, otherwise the switch uses the VPI to send the traffic to the next switch, to repeat the same procedure.

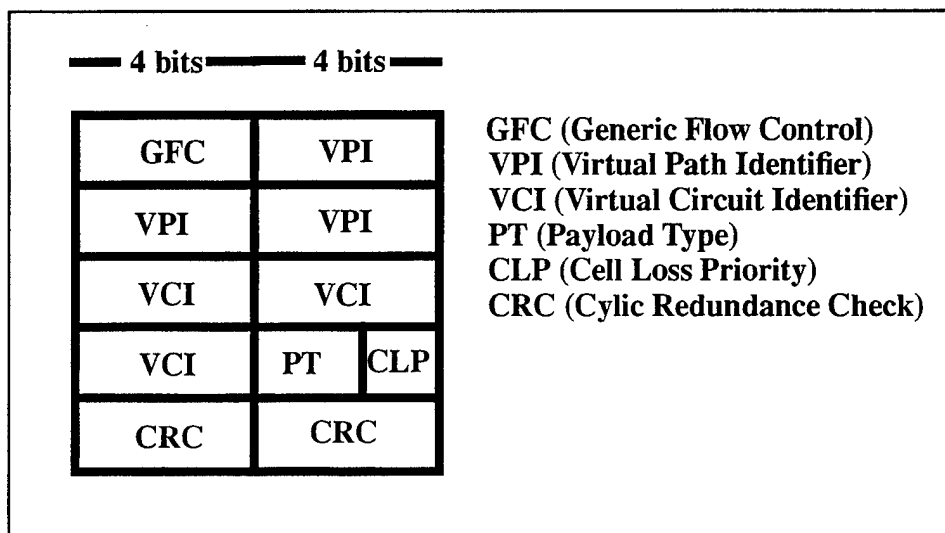


Figure 5.3 UNI Cell Header Format. After [Partridge 95]

Payload Type (PT) is used to distinguish between user traffic and different types of operations, administration and management traffic. Cell Loss Priority (CLP) is a single bit that indicates whether a cell will be preferentially dropped in the presence of congestion. Header Cyclic Redundance Check (CRC) is an error-detecting code part that is utilized for the five-byte cell header.

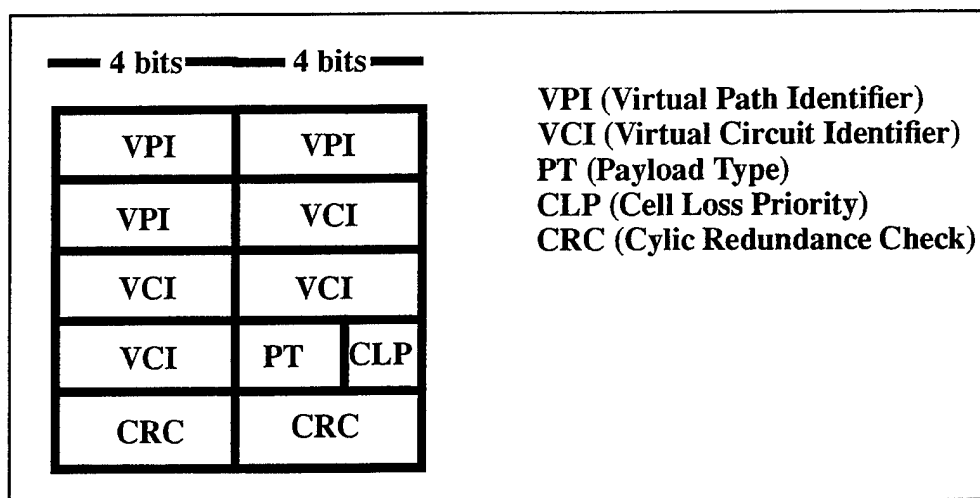


Figure 5.4 NNI Cell Header Format. After [Partridge 95]

The main difference between UNI and NNI format is Generic Flow Control (GFC) field in header of UNI cell. A four-bit GFC field gives UNI an opportunity to negotiate with the shared-access networks about how to divide cells of the different ATM connections into the network. GFC values are not yet defined. A value of zero is always used in this field [Partridge 95].

These definitions above are useful in understanding the terminology of a connection between two end points and to make a connection between two end points. Two new terms related to the connection are Permanent Virtual Circuit (PVC) and Switched Virtual Circuit (SVC).

In PVC a connection is established according to a request from the user, using the bandwidth available. Applications may use the bandwidth reserved for the connection. VPI and VCI numbers for that connection are permanent.

In SVC, VPI and VCI numbers are assigned dynamically by intermediate switches, producing a “connection-in-request” type system. The bandwidth required is allocated by the switches dynamically according to the bandwidth that is available. A

switch receives a cell on an incoming port and reads the VPI/VCI values. These values are saved for future recognition of a specific end user. The switch also looks through a routing table to find a matching outgoing VPI for the incoming one. After the switch finds a match, it replaces the VPI number in the cell header with the new one and sends it to the output for the next switch. Notice that the routing table must be built before the connections. This call setup process illustrates why ATM is called connection oriented.

So far, this section of the chapter described how ATM moves data from one point to another. ATM sends the data by cells over a connection. At this point, a description of how data is packaged into the cells is relevant. This packaging process is carried out in ATM Adaptation Layer (AAL). Various kinds of higher-level data such as datagrams, voice samples, and video frames can be divided into series of cells prior to being sent over an ATM connection. They are subsequently restored to the original stream after final receipt.

Since there are different kinds of timing requirements for data transferred through ATM connections, it is important to be able to support all of them. Originally the Consultative Committee on International Telephone and Telegraph (CCITT - now ITU) determined four different types of service. They were:

**1. Constant bit-rate applications (CBR).**

Send and receive data at constant bit rates (e.g. voice, video)

**2. Variable bit-rate applications (VBR).**

Send data at variable bit rates. This is a connection-oriented service that requires timing information (e.g. compressed video or audio) [Anujan 95].

### **3. Connection-oriented data applications.**

Intended to support applications that use a basic network service such as X.25 [Partridge 95]. There is no timing information requirement.

### **4. Connectionless data applications.**

Intended to support datagram networking protocols like TCP/IP.

AAL numbers have been given to each of these services listed above. AAL1 provides CBR, AAL2 provides VBR, AAL3 and AAL4 (merged into AAL 3/4) provides items 3 and 4 above. However it was decided that AAL 3/4 was not efficient for most data communications applications. Therefore a more efficient AAL5 (also called as Simple and Efficient Adaptation Layer- SEAL) was developed for this purpose.

Beneath AAL there are two sublayers: Segmentation And Reassembly (SAR) sublayer and Convergence Sublayer (CS). SAR sublayer processes user PDUs that are different in size and format into ATM cells at the sending site and reassembles the cells into the user-formatted PDUs at the receiving site. CS multiplexes and performs loss detection/timing recovery, depending on the type of traffic being processed by the AAL.

According to [Black 95] the use of these two sublayers in ATM is as follows:

The SAR and CS entities provide standardized interfaces to the ATM layer. The ATM layer is then responsible for relaying and routing the traffic through the ATM switch. The ATM layer is connection oriented and cells are associated with established virtual connections. Traffic must be segmented into cells by the AAL before the ATM layer can process the traffic. The switch uses the VPI/VCI label to identify the connection to which the cell is associated [Black 95].

The last topic in this ATM introduction is the media on which ATM cells are transmitted. The first thing of importance about physical media is that ATM cannot be put directly over a fiber optic cable or a wire [Partridge 95]. Over long distances, Synchronous Optical Network (SONET) frames are used to encapsulate ATM cells. SONET is also

known as Synchronous Digital Hierarchy (SDH) in the countries other than the U.S. The first data rate in SONET/SDH is 51.84 Mbps which is designated as Optical Carrier level 1 (OC-1) or Synchronous Transport Signal level 1 (STS-1) (in countries other than the U.S.). The rate can be expressed as OC-n where n is a multiplier of OC-1 (51.84 Mbps). For instance when OC-12 is referred as a rate, it should be interpreted as  $51.84 \times 12 = 622.02$  Mbps.

SONET/SDH uses frames for transmit data. Each frame consists of 90 columns and 9 rows. Thus one frame contains  $9 \times 90 = 810$  bytes. For a given OC-n, n frames are transmitted as a single unit of transmission. So for instance, OC-1 transmits data with single frames where an OC-3 does the same thing with 3 frame-groups (Figure 5.5).

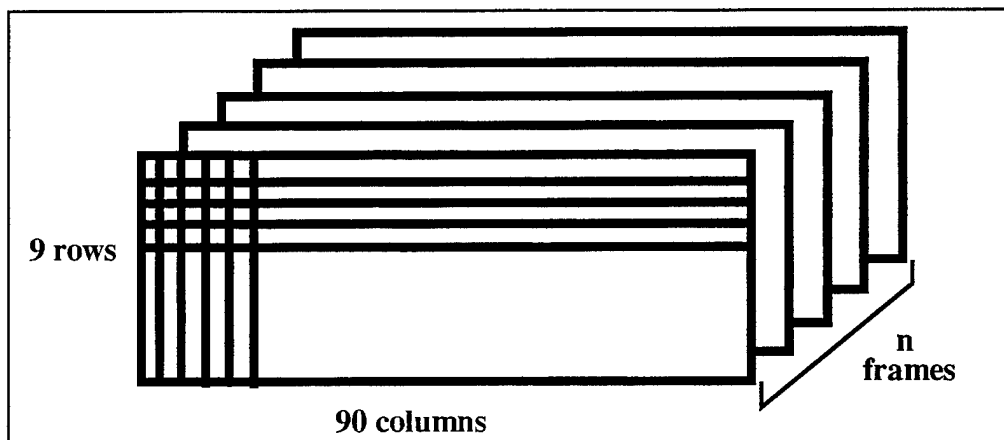


Figure 5.5 SONET/SDH Frames Used to Transmit Data

SONET is not the only physical media to transmit ATM cells. Other compatible media include Digital Signal level 3 (DS-3) which is 44.736 Mbps, 100 Mbps FDDI compatible multimode fiber interface, unshielded twisted-pair (UTP-51.84 Mbps), and shielded twisted pair (STP-155 Mbps) [Anujan 95].

## **D. INTERNET PROTOCOL (IP) COMPATIBILITY WITH ATM**

Interconnection of large-scale LAN and WAN networks across ATM requires a network layer protocol such as the Internet Protocol (IP). The operation of ATM switches, the primary mechanism for interconnecting current LANs and WANs across ATM backbones, needs to be compatible with such a protocol [Kavak 95].

In the so-called classical IP over ATM model, a logical IP subnetwork (LIS) consists of hosts and routers having the same subnetwork address and netmask [Kavak 95]. Hosts connected to the same subnet (i.e. LIS) communicate directly. However, communication between two hosts on different LISs is only possible through an IP router, regardless of whether direct ATM connectivity is possible between these two hosts.

Even though two ATM networks may be connected to each other with native ATM through ATM switches, inside these networks there may be IP subnets. So the problem is to make IP and ATM hosts understand each other by some means. An address mapping is necessary between IP and ATM addresses. IP addresses are resolved to ATM addresses by use of an ATM Address Resolution Protocol (ATMARP) service in LIS.

Initially, hosts are connected to the ARP server inside their LIS by using a built-in ATM address in the ARP server, then the ARP server uses Inverse ARP (InARP) to determine the IP and ATM addresses of the host. After that the hosts can submit a request to ARP server to get the ATM address of a given IP address. An ARP server can do this job only for hosts in the same subnet [Kavak 95].

Although the classical IP over ATM is conceptually simple and does not require any changes to existing systems, it is very limited, since IP routers are to be used between ATM subnets. In this case, any two hosts in different IP subnets that have direct ATM

connectivity between them cannot talk to each other without first visiting an IP router.

This decreases the efficiency of the ATM performance in that network [Kavak 95].

In order to overcome this limitation, the Routing Over Large Clouds (ROLC) working group has released a new protocol known as the Next Hop Resolution Protocol (NHRP). NHRP is built on the classical IP model over the networks such as ATM, Frame Relay, or X.25. These networks are called as Non-Broadcast Multi-Access (NBMA) [Alles 95]. The goal is to let a host bypass some or all of the IP routers on the way by establishing a direct connection through the ATM fabric [Kavak 95].

Simply the idea in NHRP is that every NBMA LIS in classic IP over ATM has an NHRP Server (NHS). These servers can talk to each other and keep track of the other members of their subnet. When one host wants to talk to another, NHS resolves the ATM address of the destination if it is in the same subnet, otherwise it communicates with other NHSs by using IP packets. NHRP finds the destination address so that it can be given to the source host. NHRP also has some deficiencies. One major problem is that giving a direct connection between source and destination violates basic assumptions in IP routing [Alles 95]. This problem is particularly severe with respect to multicast.

## **E. INTEGRATING MULTICAST AND MBONE WITH ATM**

The Multicast Backbone (MBone) was started in 1992. After seeing the capabilities of MBone multiparticipant real-time audio/video, other applications like conferences, DIS and distance learning were conceived. The main problem for the MBone is the bandwidth limitation that the Internet has today. The default global video stream bandwidth is 128 Kbps which is about 1-4 frames per second [Macedonia 95]. Global bandwidth for MBone is 500 Kbps. With better application tools such as *vic*, *ivs*, and *rat*,

with better data compression algorithms and with forward error correction, video and audio quality is getting better. Chapter IV and Appendix B has more information about MBone and MBone tools. Video conferencing, distance learning opportunities with the participation of many educational establishments, and the capability of large-area simulations (which will be described in Chapter VI) all encourage the trend to multicast and use MBone. ATM is a possible way to support the MBone with high-bandwidth links.

There is no specific support in the “classical IP over ATM” protocol for multicast [Laubach 94], since “classical” appears to be misleading euphemism for unicast. There are a couple of solutions that have been proposed. Multicast Address Resolution Server (MARS) was introduced in [Grenville 96]. MARS is a kind of replacement of the ATM ARP server (ATMARP) that is introduced in [Laubach 94].

MARS serves a cluster, a group of hosts. All end systems in that cluster are set up with the ATM address of the MARS. When a node wants to participate in a multicast group, it generates an Internet Gateway Message Protocol (IGMP) report message so that all multicast routers on the subnet are informed. From then on, all multicast requests go through MARS if the destination node in a multicast activity belongs to another cluster.

Possible implementation algorithms for multicast over ATM are still being explored by the Internet Engineering Task Force (IETF) working group. There is no standard for multicast over ATM. Even though there are a few ATM switches of different companies supporting proprietary versions of multicast over ATM, they are not compatible with each other and not compatible with multicast IP. This is big handicap for researchers interested in multicast and ATM.



## F. ARRANGING LONG-HAUL ATM CONNECTIONS

ATM has been used in LANs for a couple of years. However long-distance ATM connections are essential if low-latency or high-bandwidth applications need to be run across long distances. An innovative long-distance ATM WAN was tested as part of the SuperComputing (SC) 95 conference. Video applications at different levels of demand were run in a heterogenous ATM network between San Diego, California, Portland, Oregon and Albuquerque, New Mexico [Naegle 95]. Even though the compression rates of the computers did not allow using the full speed of the link (OC-3 at that experiment) satisfactory video quality was achieved. Other long-distance applications (such as DIS) are highly dependent on real-time latency in addition to bandwidth. All communications are limited to speed of light beside the limitation of high bandwidth. Light makes a round trip between west and east coasts of U.S. in about 30 ms. In order to meet human factors requirements explained in Chapter VI, it is necessary for any round-trip message to not exceed about 100 ms to achieve interactions in a virtual environment. Thus acceptable latencies coast-to-coast using ATM are conceivable. In summary, the variables in long distance latency are ATM switching time, source/destination computer process time, and light transit time through fiber. ATM switch process time is getting better and better, and the average process time today as well as connection bandwidth is not a barrier to the real-time use, even though the ATM capable links are quite expensive and it may take several years to have a cross-country ATM network. The most important technical impediment to very low latency appears to be processing time at the end hosts.

## G. NPS ATM LAN REPORT

NPS has been involved in ATM since 1995. ATM is used in the NPS System Technology Lab (STL) and NPS Computer Center. The first goal was to establish LANs in these two places, then to connect them together and finally to connect to the outside world.

In the first step, two SGI Indy computers were selected to install ATM Network Interface Cards (NICs). In order to prevent a routing loop in the existing IP LAN, Indys were given a second ATM address, so that any ATM cell would not jump into IP network. These two machines were experimented on as peer-to-peer ATM links without any switch between them (Figure 5.6). This was done by setting up a PVC between the machines.

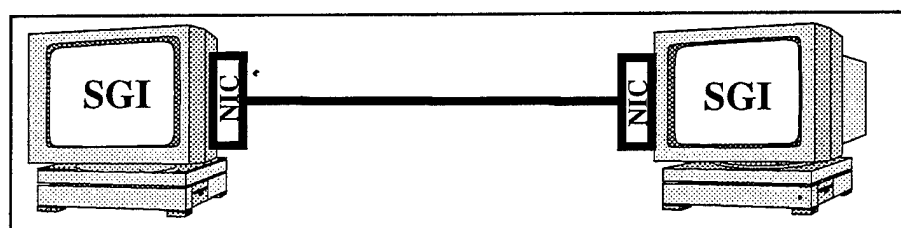


Figure 5.6. Peer-to-Peer ATM Without Any Switch

In the second step, a Cisco A-100 ATM switch was put between the two machines, to support an ATM link simulating an ATM LAN configuration (Figure 5.7).

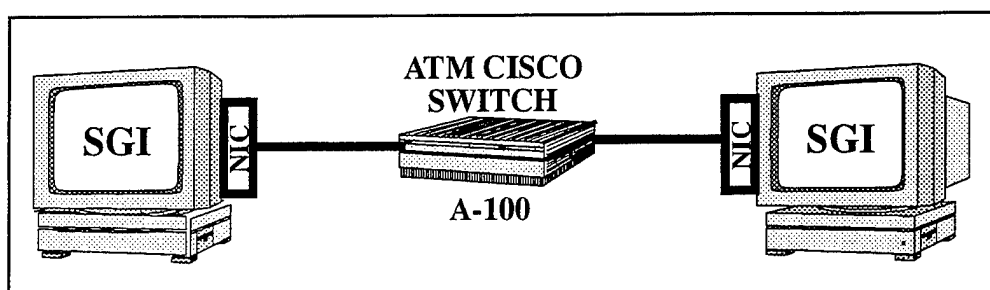


Figure 5.7 ATM LAN with One ATM Switch

In the third step, a second Cisco A-100 ATM switch was added into the LAN near the other switch, so that the simulation of two different LANs was achieved (Figure 5.8).

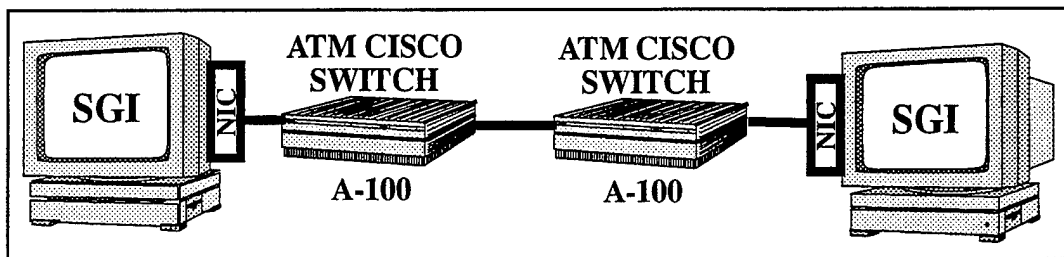


Figure 5.8 ATM LAN Simulation by Using Two Nearby ATM Switches

In the fourth step, STL was connected to Computer Center physically through a PVC connection again. Hence, instead of simulating two different LANs, the system was configured as two physically separated LANs (Figure 5.9).

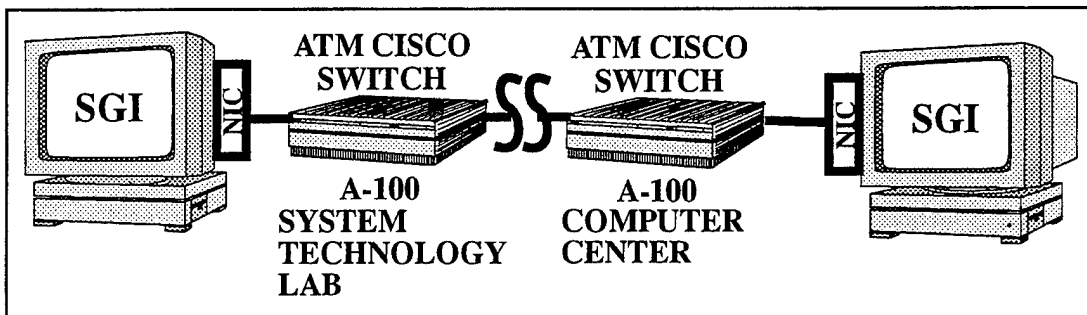


Figure 5.9 ATM LAN Configuration With Two ATM Switches in Separate Places

In the last step, NPS was connected to University of California Santa Cruz (UCSC) through Monterey BAY NET ATM PVC connections (Figure 5.10).

The follow-up goals are:

- Using SVCs inside the school and between UCSC and the school
- Using multicast and MBone over ATM inside and outside the school
- Adding security features to ATM (i.e., Kerberos)
- Going across the country

Significant problems with ATM exist and can be summarized as follows:

### 1. Interoperability between switches

There is no way to guarantee communication between switches. This was seen in many communication problem encountered between different proprietary switches.

Switches have different communication features and they are not able to communicate with each other.

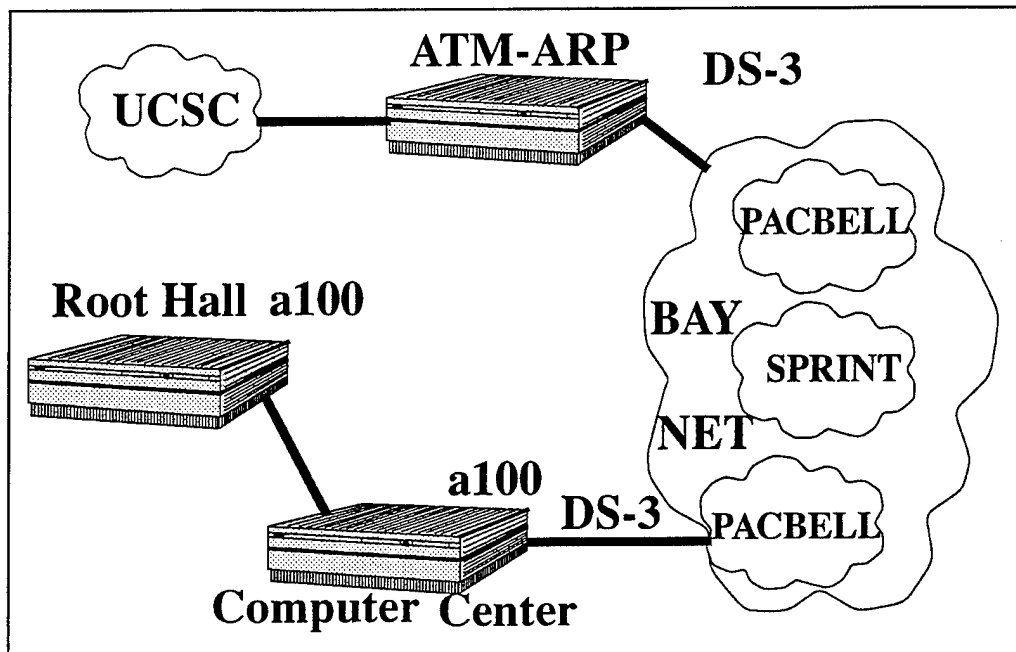


Figure 5.10 NPS ATM Connection With UCSC

## 2. Incompatibility with IP

There is no native way to multicast with ATM. There is a lot of effort going into solving the IP and multicasting problems, but so far no acceptable solution has been found.

## 3. Long-Haul Connectivity

Myriad long-haul problems exist. These problems are especially difficult due to the change in the regulations concerning Regional Bell Operating Companies (RBOC)'s being long-haul carriers. This includes setup and tariff issues.

## 4. Insufficient Trained Expertise

The human engineering problem is currently almost insurmountable. The "expertise" that exists in the ATM field is minimal due to the immaturity of the

technology. No one at NPS had ever dealt with ATM prior to our purchasing the switches. All the expertise that we had was learned through trying to establish the NPS ATM LAN. Trying to get assistance is next to impossible due to the fact that so few people have any proficiency in ATM.

### **5. Crossover Lacking**

If a connection is broken, there is no standby connection waiting to immediately take over. This scenario is heightened in the already problematic multicast situation.

More information about the NPS ATM LAN can be found in [Courtney 96] and [NPS ATM LAN].

## **H. BAYNET REPORT**

According to [Garcia-Luna 95] the objectives of Monterey ATM BAYNET are:

- A new educational paradigm (interactive, exploratory, current, distance (independent), and life-long learning opportunities for the 21st century schools, government, and industry of the Silicon Valley and Monterey Bay region.
- Ubiquitous access and timely delivery of environmental and oceanographic information to users in the various economic sectors of the Silicon Valley and the Monterey Bay region.
- Innovative information products and services that forge new linkages and collaborations between economic sectors and geographic regions
- Dynamic dissemination mechanisms for providers of public information products and services.

Two commonly used terms in BAYNET project are “teleducation” and “telescience”. Teleducation is equivalent to distance learning. Telescience can be described as remote visualization, and the control of remote experiments and interactions with remote scientists.

BAYNET is an California Research and Education Network (CalREN) project.

From the point of this thesis, the important accomplishments can be explained as follows.

### **1. Distance Learning Applications**

Distance learning applications were utilized over ATM links between UCSC and UC Extension at the first step and between the Monterey Bay Aquarium (MBA) and Monterey Bay Aquarium Research Institute (MBARI) at the second step. A later goal will connect these links to each other and to other educational services.

### **2. Bay Link Application**

In order to show the Monterey Bay submarine canyon ecosystem to a larger world, MBA/MBARI and the San Jose Technology Museum of Innovation (SJTMI) were connected to each other by ATM networks. They used proprietary video compression hardware and proprietary distributed multimedia software.

By using the Bay Link capability, students and visitors at the SJTMI can interactively participate in the exploration at the Monterey Canyon with MBARI scientists. This event is carried out in real time with full motion video from the bottom of the Monterey Canyon by using a remotely operated underwater vehicle and its camera.

This application worked because the principals spent a lot of money on proprietary hardware, software and technical consultants. Thus it is of limited use to this project because it is not open and not IP-compatible.

## **I. REGARDING ATM FOR MBONE-COMPATIBLE DISTANCE LEARNING**

ATM is promising for faster, more trusted, higher-bandwidth networks. Since its physical layer must be supported by complex network connections, it will take some time to complete an ATM network around the country or around the world. It will also continue

to have reliability problems since it violates yet another Internet design principle by pushing signaling complexity into the switches, rather than keeping complexity at the end hosts. However ATM continues to improve. There have been several experiments at long-distance ATM. The Bay Area Gigabit NETwork (BAGNET) covered the San Francisco Bay Area (explained in Chapter II). BAYNET covered a real-time Bay Link experiment (May 5, 1995, it was the first demonstration of a transcontinental end-to-end ATM application with the participation of two high schools, one in North Carolina and one in Illinois [Garcia-Luna 95]). CANARIE covered an across-the-country network in Canada as well as the INET96 exhibition which covered several countries around the world. There are many other experiments in Europe, and in Japan. Unfortunately, in each case a great deal of work was required to set up long-haul links, and circuits were permanently torn down immediately after use.

For the time being, existing IP networks can be included in the ATM networks by using inadequate protocols like classical IP over ATM. There are some problems in ATM shown in Figure 5.11.

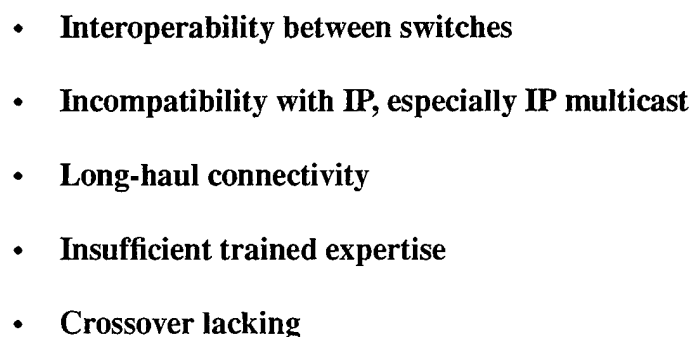
- 
- **Interoperability between switches**
  - **Incompatibility with IP, especially IP multicast**
  - **Long-haul connectivity**
  - **Insufficient trained expertise**
  - **Crossover lacking**

Figure 5.11 Significant Problems with ATM.

The importance of multicast in applications such as simulation, scientific

visualization, distance learning, video conferencing and data sharing is well understood. Efforts to improve ATM networks will not end soon. Hopefully these serious ATM flaws can be corrected and ATM will be useful for Internet-compatible multicast-based distance learning.

## **J. SUMMARY**

ATM is a new technology designed to meet high-bandwidth and low-latency requirements of existing networks to support various types of traffic such as data, voice and video. However, significant problems with ATM exist. Interoperability problem between ATM switches, incompatibility with IP multicasting, long-haul connectivity problem, insufficient trained expertise and crossover lacking are the most important problems. Because of these problems, ATM is not ready for integrating with MBone and multicast for affordable distance learning purposes. When these serious ATM flaws are corrected, ATM may be useful for Internet-compatible multicast-based distance learning.



## **VI. DISTRIBUTED INTERACTIVE SIMULATION (DIS) PROTOCOL AND MBONE**

### **A. INTRODUCTION**

This chapter explains the DIS protocol and its use. Section B gives background information on DIS. Section C introduces the features of DIS, problems and solutions to some of these problems. Section D explains the use of DIS with MBone, limitations and future work.

### **B. BACKGROUND**

Military warfare modeling goes back centuries. It was developed and became more structured in the 19th and early 20th century. The Japanese used gaming before the attack on Pearl Harbor, and the U.S. Navy War College wargamed possible Pacific operations before World War II. In the 1970's simulations became more sophisticated by allowing for separate interactions between classes of weapons but there was still no human intervention in the system [Davis 95].

In the early 1980's, microprocessor technology began to produce less expensive computers and affordable local and wide-area networks became available to connect computers. Eventually with these new technologies a new era in simulators started. It became feasible to consider developing large networks of simulators that might be connected for operation in real time. In 1983, ARPA developed the SIMulator NETworking (SIMNET) Project. The first conceptual demonstration was conducted in late 1984, and the first demonstration involving real-time, out-the-window graphics was conducted in late 1985. The first platoon-level system having image generation

capabilities was installed in 1986. The first helicopter simulators were installed in 1987 [Miller 95].

Since SIMNET was designed for Ethernet technology and relied on broadcasting, it was hard to extend from a LAN to large distributed networks. After the Gulf War in 1990, the necessity for large-scale simulations with as many as 100,000 entities was envisioned. The inefficiency of SIMNET protocol for that number of entities made researchers look for a more sophisticated and feasible protocol for the simulators. By late 1992, the initial set of Distributed Interactive Simulation (DIS) standards was agreed upon. In March 1993, the first standards were formally approved [Miller 95]. Currently DIS can support several hundred simultaneous entities. Work continues to improve DIS efficiency.

## **C. DIS PROTOCOL**

### **1. Introduction**

The DIS Vision document [DIS Steering Committee 94] describes the domain of interest as follows.

The primary mission of DIS is to define an infrastructure for linking simulations of various types at multiple locations to create realistic, complex, virtual 'worlds' for the simulation of highly interactive activities. This infrastructure brings together systems built for separate purposes, technologies from various services and permits them to interoperate. DIS exercises are intended to support a mixture of virtual entities (human-in-the-loop simulators), live entities (operational platforms and test and evaluation systems), and constructive entities (wargames and other automated simulations) [DIS Steering Committee 94].

DIS may be defined as a group of standards being developed by the DoD, industry and academia to provide a basis for interoperating many different hardware and software platforms [Macedonia 95].

The main areas for the development of standards in DIS are described below.

#### ***a. Protocols for Data Interchange***

Some of the points in developing are precise identification of data items, a common representation of data items, Protocol Data Units (PDUs) and dead-reckoning algorithms.

#### ***b. Communication Architecture***

Some of the related areas are type of addressing (unicast, multicast, broadcast), reliability, determining bandwidth requirements, constraints, and performance capabilities.

#### ***c. Security***

Development in security consists of establishment of a security policy and security service performance requirements, publication of security guidance documents, and security accreditation guidelines.

#### ***d. World Environment Representation***

Issues for achieving environmental representation among heterogeneous simulators, simulations, and range systems are identifying common sources for environmental data, creating standards for the representation of that data, creating repository databases for the collection and storage of the common data.

#### ***e. Computer Generated Forces (CGF)***

CGFs replaced Semi-Automated Forces (SAFs), designed to simulate the externally visible behavior of forces without requiring large numbers of manned simulators and people to operate them and to provide exercise for supervisory control over units that may have many vehicles [Hafer 95].

Many aspects of the SIMNET protocol such as its general principles, terminology

and PDU formats have been used also in the DIS standards [Macedonia 95]. The entity State PDU (ESPDU) structure is shown in Figure 6.1. ESPDUs can be used for reporting the change in status of moving entities. All 27 different PDUs are structured like ESPDU with fields and records designed to transfer the different types of information required for a common synthetic environment. The variety of PDUs developed are used for exchanging different types of messages between the entities. For instance, the ESPDU provides the means for reporting the change in status of moving platforms. Other types of PDUs provides related information with their names, such as Fire, Detonation, Collision.

## **2. Networking Requirements for DIS**

### ***a. Having Real-Time Simulations***

According to various studies, human users begin to perceive delay at about 100 ms. In DIS application, it is important to have low latency to achieve realistic real-time simulations. For tightly coupled units (such as aircraft formation) default values have been defined as 100 ms where as for all other cases it has been defined as 300 ms [Pullen 95]. Up to five seconds is allowed for slower-moving or stationary entities. Real-time requirements in a network can be achieved by using UDP, but that brings up another requirement which is high reliability. Detonation and Fire PDUs are required to be delivered more reliably than ESPDUs. Reliability can be provided by using transmission control protocol (TCP) but it delays delivery of sizable blocks of data whenever a packet is lost, and therefore is inconsistent for real-time delivery [Pullen 95].

<b>Field Size (bits)</b>	<b>Entity State PDU Fields</b>	
<b>96</b>	<b>PDU Header</b>	<b>the information needed by any receiving node to properly characterize and operate on the data being received</b>
<b>48</b>	<b>Entity ID</b>	<b>information about the simulation application and entity generation data carried in the PDU</b>
<b>8</b>	<b>Force ID</b>	
<b>8</b>	<b># of Articulation Parameters (n)</b>	
<b>64</b>	<b>Entity Type</b>	
<b>64</b>	<b>Alternative Entity Type</b>	
<b>96</b>	<b>Entity Linear Velocity</b>	<b>information about the current state of the entity. These records provide the position, rate of movement, orientation and parameters needed by dead reckoning algorithms which describe the entity originating the information</b>
<b>192</b>	<b>Entity Location</b>	
<b>96</b>	<b>Entity Orientation</b>	
<b>32</b>	<b>Entity Appearance</b>	
<b>320</b>	<b>Dead Reckoning Parameters</b>	
<b>96</b>	<b>Entity Marking</b>	
<b>32</b>	<b>Capabilities</b>	
<b>n*128</b>	<b>Articulation Parameters</b>	<b>information about articulated parts which are attached to the platform being represented</b>
<b>Total Entity State PDU size = (1152 + 128n) bits where n = number of articulation parameters</b>		

Figure 6.1 Entity State PDU. After [Pullen 95]

### ***b. Multicasting***

Multicasting is a means of data transfer from one host to the other(s) in addition to broadcast and unicast. In multicast, it is possible to have a capability of one-to-many and many-to-many data transfer for a special group of hosts participating in a session. In a distributed large-area network, multicast is a desirable feature. Only one copy of a message is sent to the members of a multicast group, minimizing bandwidth requirements.

### ***c. Security Issues***

Since DoD DIS applications have sensitive data, a means of encryption to provide security in the simulation wide-area network is paramount.

A second issue for security concerns multicast. If we want to use multicast in the network and have several multicast groups, then we must have key management for distribution to the groups. Furthermore, joining and leaving existing groups dynamically, participating in more than one simulation, international simulations, and multi-level security are considered other important management issues [Pullen 95].

### ***d. Capacity of a Network***

After the Gulf War in 1990, the necessity of having a large number of entities in the simulation exercises became more important. If such an exercise were conducted for 100,000 entities (which is the goal of DoD) then we would have at least 175 Mbps on the network [Miller 95]. That number could be as high as 375 Mbps [Macedonia 95] and this presents serious problems, because 375 Mbps of network bandwidth to each computer participating in the simulation is unrealistic for an affordable system [Macedonia 95].

### 3. Problems With DIS

#### *a. Great Amount of Bandwidth and Computation Requirements*

As mentioned above, a simulation involving 100,000 entities requires a bandwidth of 375 Mbps. Every entity is tracked and updated, and maintaining the update state is achieved by sending PDUs to all other entities by the host entities. The problem with this scenario is that, if the entity is moving, its position, velocity, and orientation will change and the PDUs which has a lot of other information in them will be broadcast to all other entities. This redundancy is a very bandwidth-consuming process. It is even a larger problem if we think about inherent network redundancy in broadcasting. This is a principle reason for a bottleneck in large-scale simulation environment.

The DIS protocol transmits acceleration, velocity and position data whenever a remote object exceeds a dead-reckoning threshold or a 5 second time-out period. Dead-reckoning algorithms use first- or second-order models to predict the future object location. Because the algorithms are highly real-time dependent, the conversions in updating process are heavily computational [Singhal 95].

#### *b. Security*

In large-scale distributed simulation exercises, there are certainly some security requirements and access authorizations for participants. They need to exchange some information with the other participants. However, one encryption technology often used today (known as link encryption) encrypts all of the stream passing through a point-to-point data link. Even though this form is widely used, it has security constraints on the nodes because insecure intermediate nodes cannot transfer these streams [Pullen

95]. The other encryption method, end-to-end packet encryption, does not encrypt the header of the packet. It is more flexible since it allows use of insecure intermediate nodes in the network [Russell 91]. However the only end-to-end encryption system approved for military use is bound to a maximum data rate of T1 link (~1.5 Mbps) [Pullen 95].

### ***c. Multiplexing/Demultiplexing of Media***

The current DIS protocol requires an application layer multiplexing/demultiplexing for real-time data (e.g., simulation packets, audio, and video) rather than the network or transport layer. It is difficult to build DIS applications that can efficiently use all kinds of data such as audio [Macedonia 95].

### ***d. Others***

Some problems are explained in [Macedonia 95] and can be summarized as follows:

- For large, heterogeneous simulation networks, it is necessary to have an “on-demand” data distribution to achieve efficiency. There is no such mechanism in DIS.
- DIS does not have any method to communicate all the abstractions needed to present a complete and consistent view of reality (e.g., clouds, weather, smoke)
- Another problem is fidelity. Every simulator in DIS applications is assumed to be truthful. In a large-scale heterogeneous simulation, the quality of realism that each simulator has affects the realism of the exercise (e.g. a highly realistic simulator cannot compete against a less accurate one).

## **4. Possible Solutions to Problems**

There are a variety of ways to deal with bandwidth requirements and heavy computation. Multicasting is the first one. Multicast minimizes network bandwidth. The network is not used unnecessarily by sending packets to every entity even when unneeded. Another advantage of multicast is that it reduces the computation at the entities. Entities take only the information (PDU) they need because multicast can be subscribed or



discriminated against in the network interface card hardware rather than the application layer software. Thus they do not need to perform extra computations to ignore unsubscribed PDUs.

According to [Morrison 95] there are two approaches to deal with the complexity of the DIS protocol. One is the “Newtonian Protocol” by the Defense Advanced Research Project Agency (DARPA). The main idea is to combine the many special-purpose DIS PDUs (like the collision and detonation) into lesser numbers of PDUs.

ATM is a promising approach for low-latency, high-speed network connectivity required by large-scale wide-area distributed simulations. We have discussed ATM in Chapter V. Multicast IP over ATM is still a research area. There are some implementations of multicast IP over ATM, but for now, they lack the capability for working with different brands of ATM switches.

Instead of using the dead-reckoning algorithm that is used by DIS now, an algorithm like Position History-Based protocol described in [Singhal 95] may be more efficient. Some of the advantages mentioned in the reference can be summarized as follows:

- It tracks remote objects more smoothly.
- At wider thresholds, it smooths the motion, while DIS protocol exaggerates it.
- By using timestamps to synchronize the remote tracking at receiving hosts, it is effective in addressing latency and jitter issues in real-time visualization systems.
- It transmits a total of 386 bits, where as DIS protocol transmits a total of 672 bits. The history-based protocol can transmit 1.75 times as often as DIS and still reduce bandwidth.
- The lighter packet load is important for supporting large virtual environments containing large number of participants.
- There is no additional computational overhead on sending or receiving hosts, and the algorithm can actually reduce computational load.

For key management, end-to-end encryption and bandwidth limitation, there is a

project mentioned in [Pullen 95]. As indicated above, the only end-to-end encryption system currently approved for military use is good only to a maximum data rate of T1 level. When National Security Agency (NSA) fields a new end-to-end encryptor called "FASTLANE" which will support ATM, it is expected to provide the data rates required by DIS. This encryptor standard also has some advanced features such as "key agile," the ability to apply multiple encryption keys dynamically, and will achieve some key management goals. Multicast on ATM by using FASTLANE is a future research area.

#### **D. DIS AND MBONE**

As shown in Chapter VI, the MBone enables the distribution of IP multicast over the Internet. Since researchers have been looking for opportunities to provide multicast capability to DIS applications, the MBone is an excellent candidate for long-haul connectivity.

NPSNET was the first DIS application to use IP multicast and also to be tested experimentally over the MBone. The NPSNET-IV networked virtual environment was developed at the Computer Science Department of the Naval Postgraduate School (NPS) in Monterey California. By having IP multicast capability, sites that participate in distributed simulations can be connected directly via MBone.

After SIGGRAPH 93, the multicast version of NPSNET-IV was completed. The first communication was established between SRI in Menlo Park and NPS. That event presented an important challenge for interactive simulation. Despite a hostile network environment, NPSNET-IV had a small amount of perceptual latency. A more detailed explanation can be found in [Macedonia 95].

These MBone experiments were important because they showed the use of

multicast in DIS applications. However, the number of the participants were far from the DoD goal. T1 lines were used to connect sites, so the bandwidth was limited. There was a perceptual latency which can make the simulation performance far from real-time requirements. Dead-reckoning algorithms usually can reduce this perceptual latency to acceptable level.

Researchers continue looking for better methods for instrumenting 3D simulations. Some new ideas are explained in [Brutzman 96]. We believe it is physically achievable to have Large-Scale Virtual Environments (LSVEs) across the country without simulator sickness for fully represented and fully immersed humans. There are two fundamental steps needed to permit the transition to building useful LSVEs: the Cyberspace Backbone (CBone) and Virtual Reality Transfer Protocol (vrtp).

The network proposed for the CBone is a combination of the National Transparent Optical Network (NTON) and other extensions [Brutzman 96]. By having a predictable high-speed network with guaranteed services, we can reduce the transmission delays across the network and perform repeatable experiments to optimize cross-network performance.

The second step is vrtp. According to Brutzman:

“vrtp is to be the applications layer protocol used for communicating state information among the various participants in internetworked LSVEs” [Brutzman 95].

We intend to use the Virtual Reality Markup Language (VRML), a standard language for describing interactive 3-D objects and worlds delivered across the Internet [Carey 96]. For the high-bandwidth and low latency requirements of virtual environments, many of the client-server design assumptions of the Hypertext Transfer Protocol (http) are

no longer valid. vrrp is needed to take advantage of available transport layer functionality. vrrp will add the latency-tolerant real-time behaviors functionality (e.g., audio/video streaming and DIS-like behaviors) to client-server capabilities. Details about CBone and vrrp can be found in [Brutzman 96].

## **E. SUMMARY**

This chapter describes the DIS protocol, problems with DIS, and some possible solutions for those problems. DIS is an important demonstration of the possible ways of using virtual environment in networks. DIS concepts make possible the use of the Internet-based distributed simulations for purposes such as distance learning. The algorithms are getting better, the connections are getting faster and larger. 3D graphics are becoming more accessible by using VRML. Ongoing research into protocols such as vrrp, 3D graphics and distributed simulations hold further promise for Internet-based distance learning.

## **VII. EXPERIMENTAL RESULTS**

### **A. INTRODUCTION**

Requirements, necessities and motivations on using MBone for distance learning are in Chapter IV. This chapter covers experiments carried out at NPS in which the author participated. Section B is about the MBone/Web classroom, explaining the issues that must be taken care of in the planning and implementation phases of the classroom experiments. Section C covers the AUV 96 Conference held by NPS between 2-6 June 1996 and shows the difference between a conference hall configuration and an MBone classroom, and gives important steps to manage an MBone session in a conference hall. Section D covers the same topics for the Web Content and Access workshop that was held on 23 and 26 August 1996 in the Mechanical Engineering Auditorium at NPS.

### **B. MBONE CLASSROOM**

#### **1. Goals**

The goals of building an MBone/Web classroom can be listed as follows:

- Using multicast transmission method over the existing Internet, so that a large number of people and schools can use it with no extra cost.
- Providing a valuable reference source, World Wide Web (Web), for the instructors and end users.
- Providing a distance learning opportunity for overseas military shore based stations for the unclassified classes. It may be used even in naval ships, after satellite communication came down to the real world with a convenient price/performance ratio.
- While addressing the issues above, keeping the cost at minimum, at least at an affordable level for all schools.
- Motivating follow-up researchers, and providing a reference for schools that wants to use this kind of a classroom.

## 2. Hardware

It is helpful to plan hardware requirements by asking questions about the use of the chosen classroom. Answers to these questions help produce requirements for the classroom. For the MBone/Web classroom at NPS, questions and answers are as follows:

- *How big is the classroom?*

The classroom is a medium-sized classroom, originally configured as shown in

Figure 7.1.

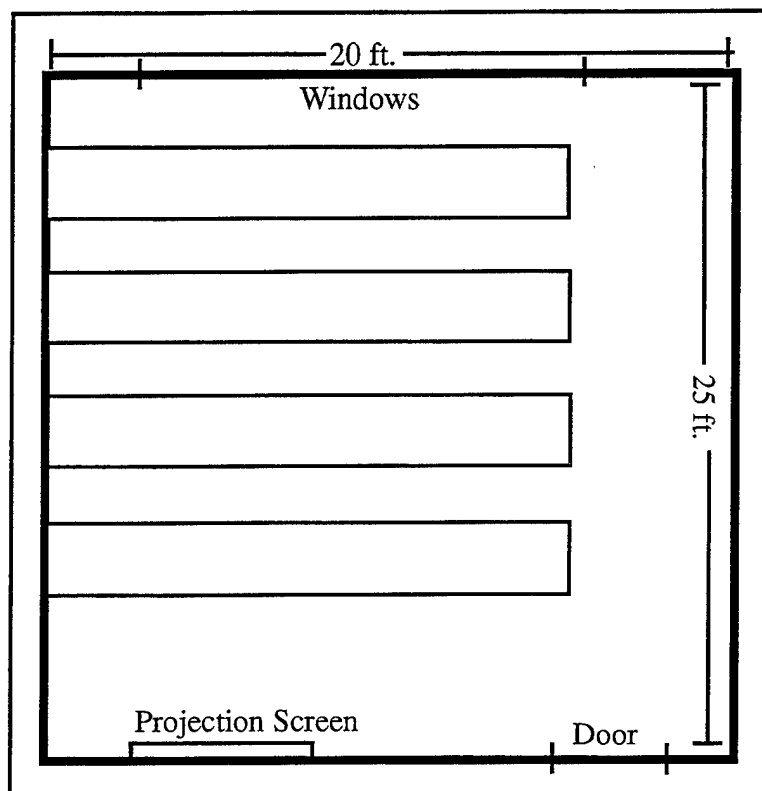


Figure 7.1 Original Appearance of the Classroom

- *What kind of equipment is there in the classroom?*

As in most classrooms, the MBone/Web classroom in NPS had one overhead projector and one projection screen.

- *What are the network and power connections in the classroom?*

The classroom had one Ethernet connection to the 131.120.63.X subnet which already is on the MBone. In almost all classrooms there are enough power outlets for some equipment. Since more electrical equipment than regular classrooms is used for distance learning, two power strips are necessary to provide power inside the classroom (Figure 7.2).

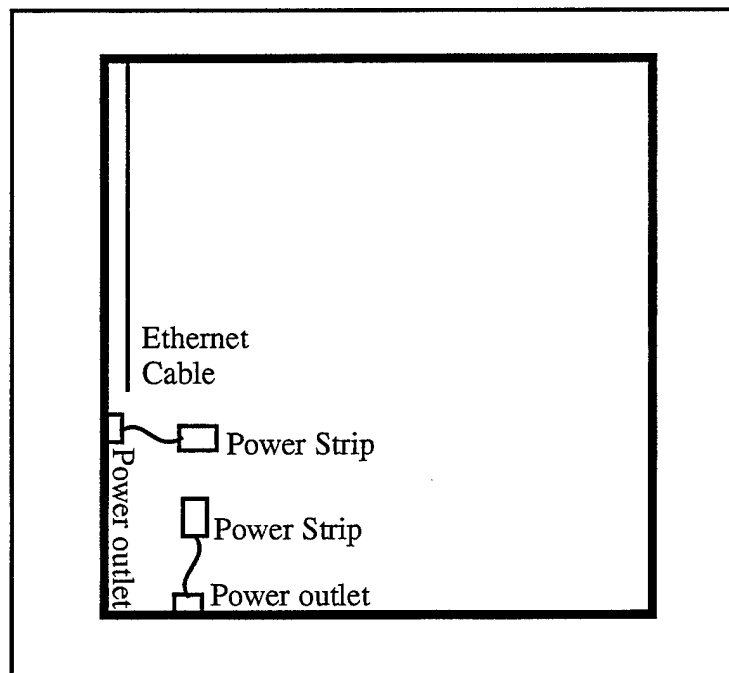


Figure 7.2 Power and Network Conditions of the Classroom

- *What are the light conditions in the classroom?*

The classroom had regular ceiling fluorescent lights (Figure 7.3), windows at the back side with dark colored curtains. The problem with these light conditions is that while the instructor is giving a lecture, the lights must be turned off to give students the opportunity of seeing slides or video projection. But at the same time, there must be enough light source so that far-end students can see the lecture classroom from the MBone session and near-end students can read or write what they have in front of them at the

desks. Thus lighting control must be improved. A new installation of directed lights on each wall (as shown in Figure 7.4) might provide better lighting conditions. However this is a major modification. Instead, rewiring the switches for the existing lights was required so that lights at the back and lights at the front of the classroom could be controlled independently (Figure 7.5). When there is a session the rear lights are turned on, hence there is just enough light source for both near-end and far-end students. This solution works well. Figure 7.6 shows the back lights in the classroom.

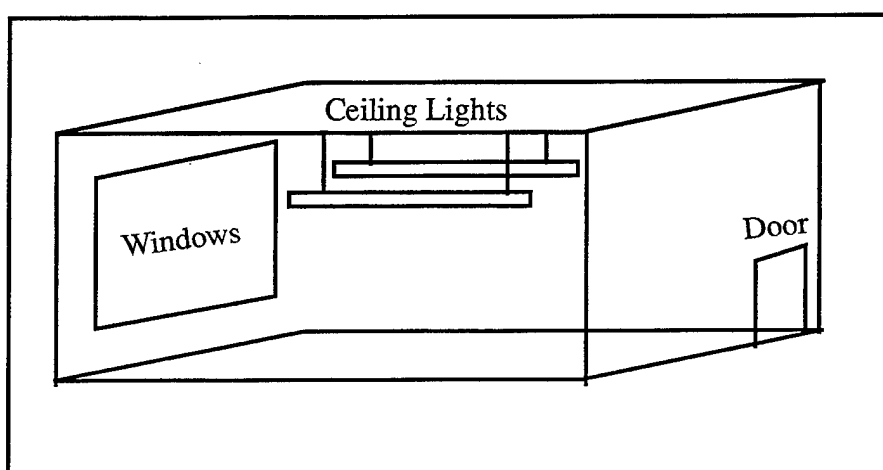


Figure 7.3 Original Ceiling Lights of the Classroom-only two banks had separate switches

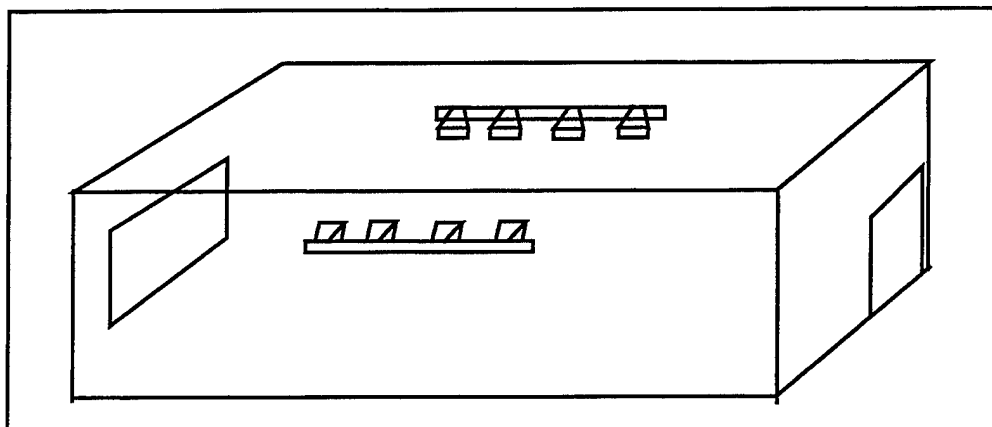


Figure 7.4 One Idea for Extra Lights. Lights Over Trails on the Wall



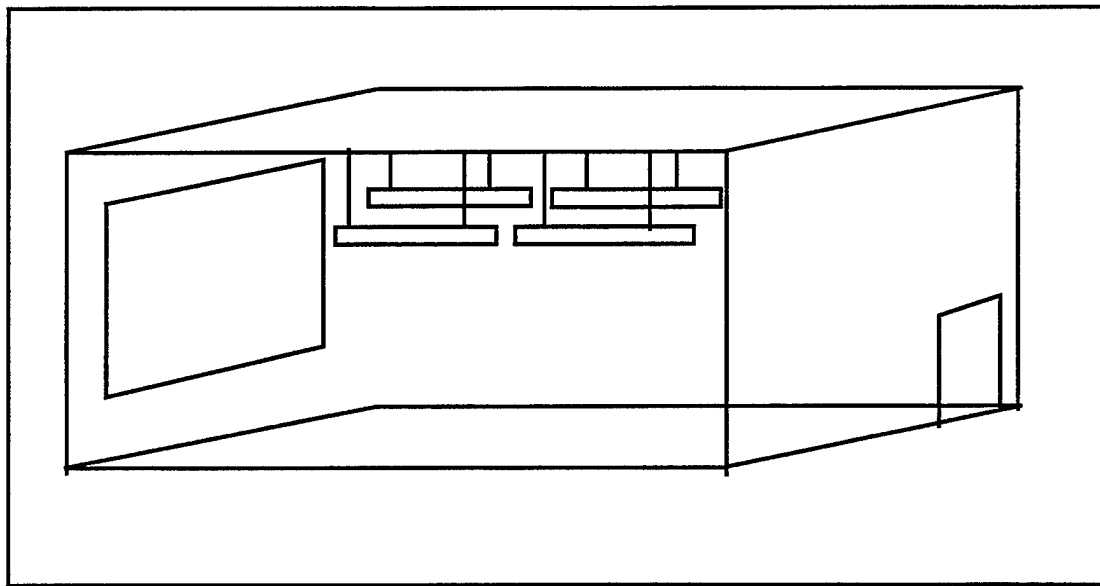


Figure 7.5 Two Fluorescent at the Back are Controlled Separately



Figure 7.6. The Back Lights in the Classroom are Turned on Separately and All Four Banks are Now Independent.

• *What may an instructor or a student want in the classroom for education purposes?*

An instructor may want to have:

- An overhead for slide presentations,
- A computer connected to the Internet,

- An overhead and a presenter to show students to reflect the computer monitor to the screen,
- At least one or two projection screens for overheads for more flexibility,
- One VCR to play video tapes,
- One video projector to reflect the picture coming from the VCR to another projection screen or a light-color wall, as it was done in NPS,
- A TV monitor to watch far-end classroom.

This last item forces the limits of MBone classroom design, since most of the computers do not have a video output on them. In most cases, the instructor may have to use a computer monitor to follow or to answer far-end students even though it is not the most convenient way. Video output cards are commercially available at additional expense.

A student may want to have the following items in addition to what the instructor may want:

- A TV monitor as a second source for watching video tapes, the monitor also helps greatly as the sound system of the classroom. In the MBone classroom, either an audio mixer or a sound system were used, since speakers of monitor were enough to hear video tape sound comfortably in the whole classroom.
- A microphone that is put on by instructor. Far-end students need to hear the instructor easily, so a wireless mike attached to the instructor was used.
- A computer to follow Web and MBone. Even though it might be useful, it would be highly expensive, and as far as this thesis was concerned it was out of question.

### **3. Software**

Software used in the MBone/Web classroom consists of a Web browser (such as Netscape Navigator, NCSA Mosaic etc.) and public-domain MBone tools.

Web browsers are more or less the same, but preferably it should have Java and 3D capability. Many of the sites in the Web are using Java and VRML 3D browsers so if an old version of browser is chosen, it may not necessarily give the anticipated picture when that site is opened.

MBone tools are also upgraded frequently. New versions of video tools, (such as

*vic*, *nv*) audio tools, (such as *rat*, *vat*) and session directories (such as *sdr*, *sd*) all must be installed on the network. In a classroom connected to a subnet in the school, there is not much to do with a single particular computer since they are available on a network basis. System administrators must be warned when a new version of these tools comes up, so that they can upgrade whole network.

#### **4. Topology**

In order to meet most of the requirements mentioned above, the following equipment was provided either from the NPS Audio/Video department or from the System Technology Lab (STL):

- SGI *Indy* workstation with a Presenter overhead projector monitor
- A TV monitor
- A VCR
- A video projector
- A projection screen
- A video camera
- A wireless microphone

The workstation needs to be near the instructor for easy use. The TV monitor should face the students. Two overheads projectors (one for slides and one for computer presenter) should be close to each other so that instructor can reach them without moving too much. Two projection screens are needed depending on locations of overheads. The video camera should be in a place so that it can cover as large a picture as it can and be operated by a nearby person when necessary. The VCR and video projector should be located in a place where anybody in the classroom can watch the tape and not obscure the picture since the instructor can not do all of these things by his/herself.

Taking these factors into account, the MBone/Web classroom was configured as shown in Figure 7.7. This configuration has been tested for six months and has worked

fine, meeting the goals of this thesis. A complete reference on configuration and building the MBone classroom can be found in Appendix E.

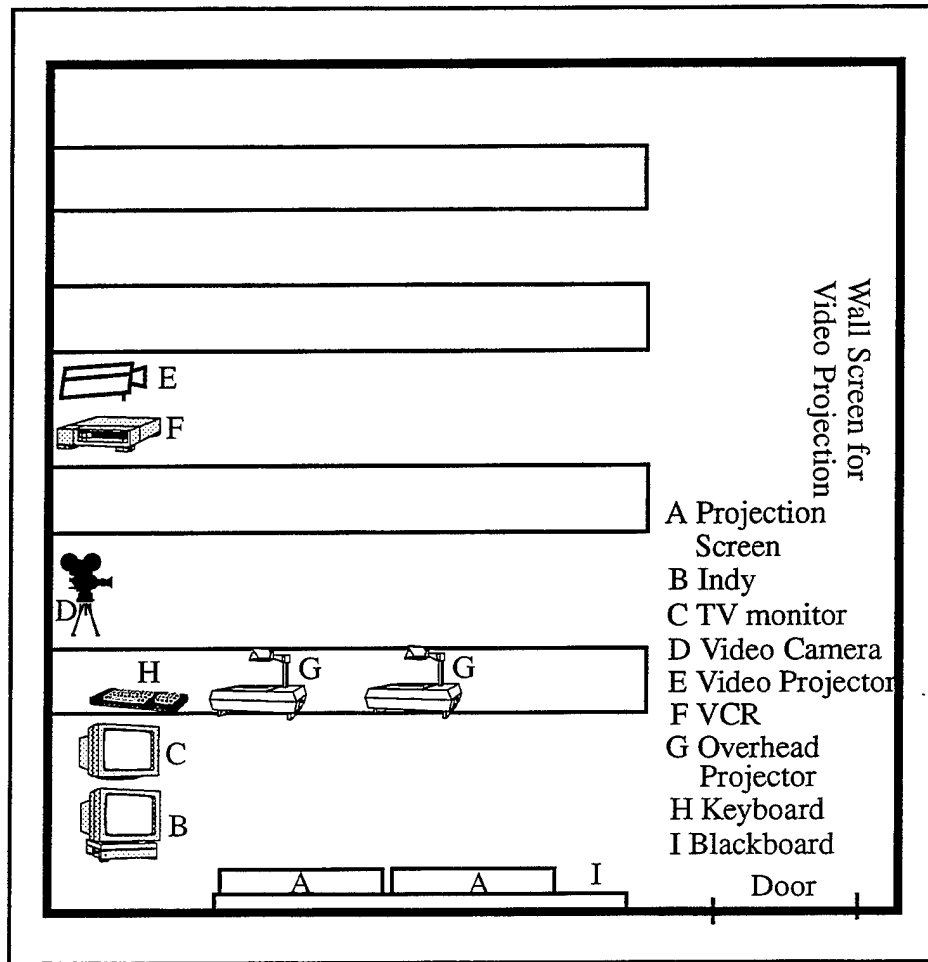


Figure 7.7 Hardware Configuration of the Classroom

The instructor can use the blackboard, use transparencies, show slides or play video tape, as well as showing a Web site. The students at the near end can watch the video tape either from the monitor or on the wall (a cheap but useful screen), while far-end students can watch them through MBone playing either from a TV monitor, a desktop computer, or a projection depending on the configuration they have.

## 5. Results

The MBone/Web classroom is one of the first experiments in this area. The author

achieved a certain level of success with this experiment. Some of the classes were carried out between California State University Monterey Bay (CSUMB). Web was combined in the classes with MBone. Video recording opportunity was also used to record some of the lectures and presentations for later playing through the MBone. The MBone/Web classroom is still used by instructors since it has been perceived as useful. Practice has shown that use of this equipment is easy and simple, which prevents the technology from obscuring instruction. Further use will likely improve it more.

## **C. AUV 96 CONFERENCE**

### **1. Goals**

Multicasting the AUV 96 Conference through the MBone was a great opportunity for NPS students to use MBone. After the experience gained with the MBone/Web classroom, the author used this conference as a second step in networked distance learning.

Equipment from the MBone/Web classroom was moved to the conference location two days in advance. The computer network was reconfigured. Since this was an important MBone event, lots of attention was paid to planning. Personnel management was especially important since an instructor and an assistant student are not enough to carry out a session as may happen in the MBone classroom.

Considering the secondary goals above, the ultimate goals may be explained as:

- To be able to manage larger events, such as conferences, exhibits, seminars, multicast properly by using the equipment belong to the school, and school workers like students and system administrators.
- To prepare a reference for the similar events for future use both by the use of NPS and other educational institutions.

## 2. Hardware

In hardware planning, similar questions to those for a classroom and answers can be helpful in obtaining the requirements. These are:

- *How big is the conference room?*

Two different rooms were used in the conference. Usually the small room had better video and audio recording conditions. In large halls, having a satisfactory level of audio is much more difficult. Even though house sound system was used in the conference room, there were not enough microphones for the audience so their questions sometimes could not be heard by the far end audiences. A solution to this problem might be using a wireless mike and hand it to the person who asked a question. However this lengthens the time for questions so instead another microphone was provided to the audience. Constant attention to the volume of the sound system is essential. In general, audio is harder to do properly than video.

- *What are the light conditions in the conference room?*

Light conditions are usually not a problem in conferences. Light controls were excellent. When the speaker wants to show a video tape or slides, lights are diminished by an assistant so that the person behind the video camera can take the best picture possible.

- *What are the network and power connections in the conference room?*

Power connections are not a problem in conference rooms since they are designed to support many power requirements. Network connectivity, on the other hand, was the biggest problem in the conference. There was no built-in network connection at the hotel. The best solution to that problem was using two wireless (Airlan) network bridges. These bridges were regular 386 PC computer with radio connections on bridging software.

Directed antennas were connected to the bridges so that when pointed at each other, they can receive/transmit packets through the air. Cellular phones were used during long-distance setup to align antennas properly.

After establishing the network connection between the conference room and the school, the remaining task was to drop Ethernet cable from the rooftop Ethernet bridge down to the conference room, and then to connect the computers to that Ethernet cable.

- *What kind of backup equipment is necessary?*

Since conferences are usually global on the MBone, backups must be provided to carry on multicasting in every situation. In this event, one other workstation with MBone tools was available which also provided network monitoring capabilities. An Uninterruptable Power Supply (UPS) was also used to protect expensive equipment.

- *What kind of equipment can the conference center support?*

Conference centers usually can help with the electrical, audio, and lightning related problems. A planning session before the conference is very helpful.

- *What are the plans for recording the conference?*

It had to be decided how many cameras are needed, e.g., a single camera for slides, audience and speakers, or separate cameras for each of them. The final lineup has to answer many questions. How do you take video tapes played by speakers, e.g., direct connection between a VCR and the computer, or just shooting TV monitor by a video camera? What kind of equipment is necessary for the cameramen, e.g., a TV monitor just to see what they are recording, since it is usually too tiring to look through a small CRT screen on the video camera for hours? We tried many of these possibilities. Most worked and only varied in convenience.

### 3. Software

Software requirements are not different than for any other MBone experiments.

This time, instead of using a network to which the computers are already connected, a new network environment was used. So MBone tools and network monitoring tools must be installed locally on the computers used in the conference.

### 4. Topology

Combining the hardware and the software requirements above, and checking with the hotel engineers led us to build the network configuration in Figure 7.8. This configuration actually belongs to the main conference center. Even though there is a size difference between the two conference rooms, the configurations were nearly the same.

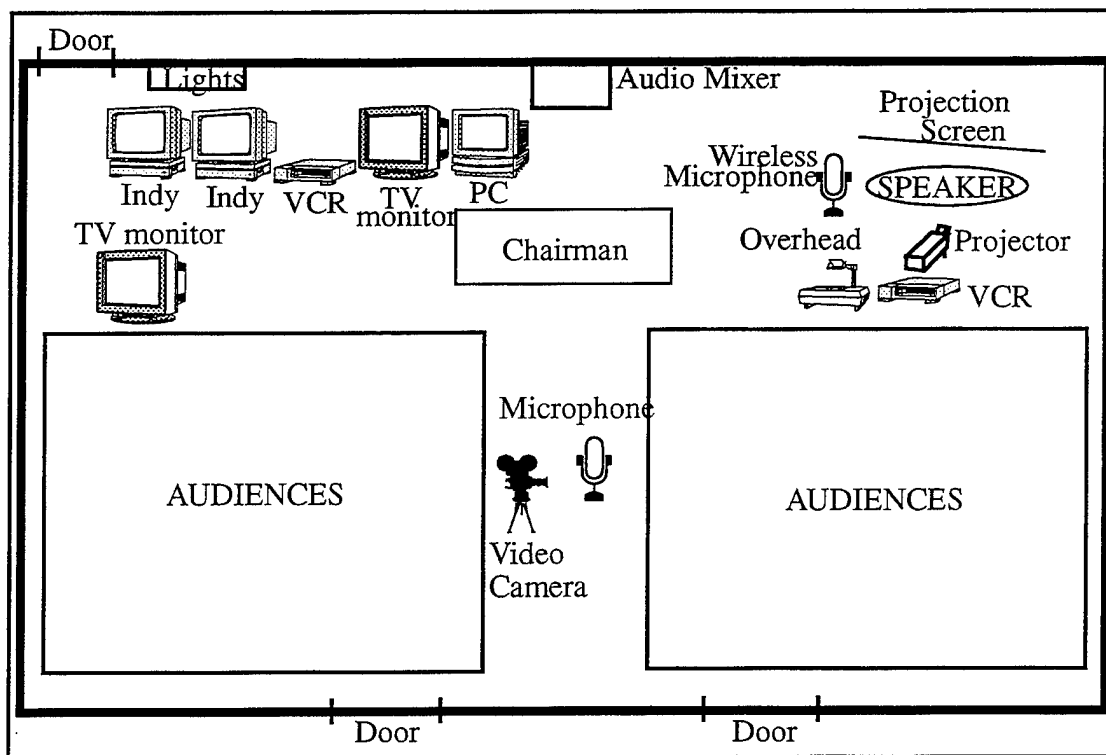


Figure 7.8 Hardware Configuration of AUV 96 Conference Room

The PC in this figure was used only to demonstrate PC MBone tools, to store digital camera pictures and prepare them for the home page about the conference, and to



make ftp/telnet connections. Events could be written in html concurrently while the conference was going on, by using that PC and Web connection. More details about the preparation and the configuration phases can be found in Appendix F. Computer layout in the conference is shown in Figure 7.9.



Figure 7.9. Workstation, PC, TV Monitor and VCR Configuration.

## 5. Results

The AUV 96 Conference let NPS and the author gain another challenging experience about MBone multicast, conference management and configuration for MBone. Documenting this event hopefully allows successive researchers to improve quality by allowing them to start from an improved knowledge level.

This conference was an opportunity of getting better picture quality from the MBone, a more flexible configuration planning knowledge, and a more realistic requirements analysis for these kinds of events in the future. Figure 7.10 gives a general appearance of the speaker at the conference. Figure 7.11 shows the picture quality in MBone. This picture was taken by a snapshot of the MBone video tool (*vic*) during the conference. As a comparison, Figure 7.12 shows a picture taken by a digital camera during

the conference.

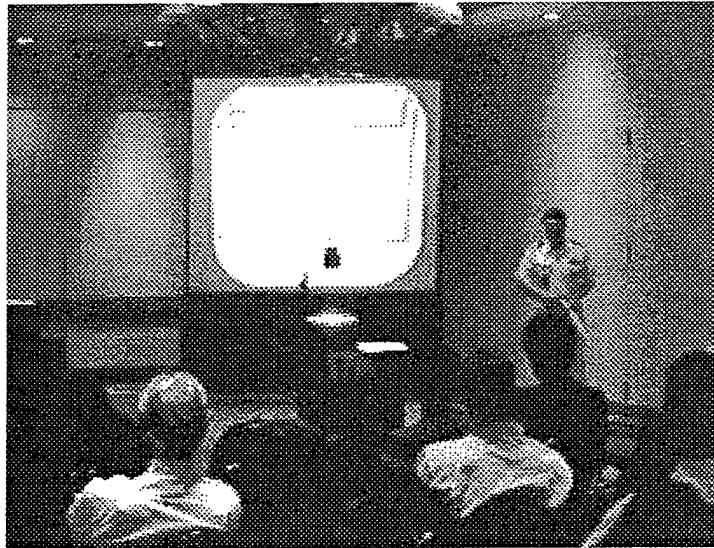


Figure 7.10. A General Appearance from the Conference.

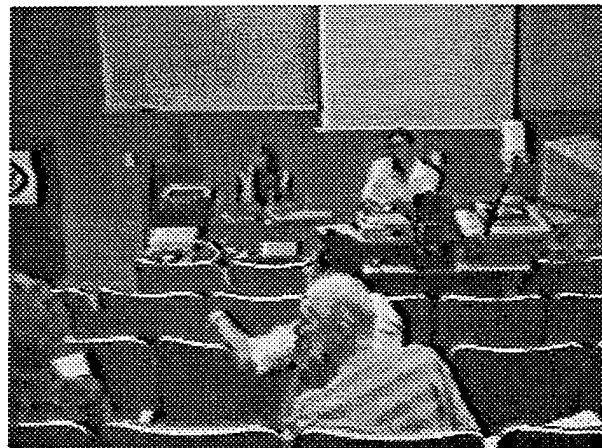


Figure 7.11. An Example of Video Quality of MBone Tools.

## **D. MONTEREY BAY WEB CONTENT AND ACCESS WORKSHOP**

### **1. Goals**

The primary goal for this workshop was to test a small auditorium environment for MBone distance learning. One reason for this experiment is to prepare a reference for the follow-up MBone users of this auditorium. Another reason was to experiment using

MBone in a different environment. Unlike the conference in a hotel, we have security at the school auditorium. Another reason was to experiment in digital video/audio recording and storage [Tiddy 96]. This is one of the first times that digital recording was done through MBone. Recording is especially important to enable any Internet site to record and play sessions at any time. More detailed information about digital recording can be found in [Tiddy, 96].

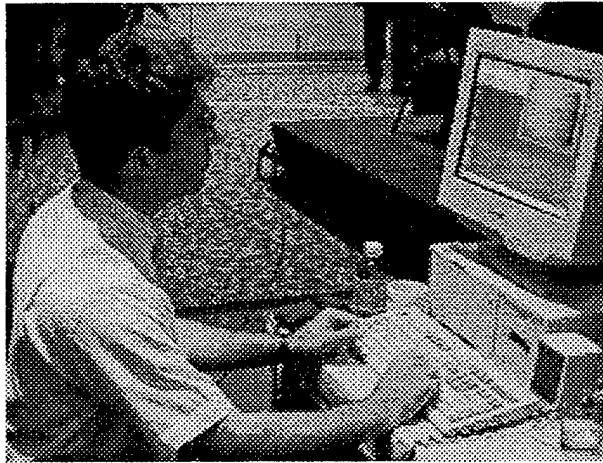


Figure 7.12. Author Monitoring Conference Multicast.

## 2. Hardware

Using the same questions as we did in the previous sections to develop requirements:

- *How big is the auditorium?*

NPS Mechanical Engineering Auditorium has a capacity of 110 people. Even though the auditorium is not small, acoustics are excellent throughout. The auditorium is shown in Figure 7.13.

- *What are the light conditions in the conference room?*

Light conditions were good in general. Lights could be controlled both from the control room and from inside the auditorium. The problem with the lights was that there

was not enough directed lights for the speakers. So, when the lights were dimmed for better view of the projection, the picture of the speaker taken by the video camera was almost dark. In the workshop, we tried to compensate for poor lighting design by changing the levels of the lights. This problem needs to be corrected.

- *What are the network and power structure in the auditorium?*

There was one thin Ethernet connection in the control booth, and one in the auditorium on the stage. New IP numbers were obtained from the ME department system administrator. So, we did not have any network connection difficulty during the workshop. Power, on the other hand, was a problem. Even though there were enough outlets in the control booth, there were not many inside the auditorium. With two power strips in a single outlet, the powerstrip's circuit breaker tripped and shut down a couple of times. We corrected this problem by changing one of the power strips to another outlet on the wall at the site of the auditorium. Power outlets in the middle section of the auditorium (where most of the equipment was used) were not rated high enough to give the power needed. Another problem was that there was no way to pull cable between the auditorium and the control booth, other than by pulling the cables under the doors which was not a proper way. Therefore we couldn't put the video camera inside the auditorium. Instead, we located it in the control booth. In this case we had to record behind the glass window of the control booth. Sometimes the light reflection on the glass was recorded unintentionally.

- *What kind of backup equipment is necessary?*

An extra workstation and an Uninterruptable Power Supply (UPS) is necessary as backup equipment.

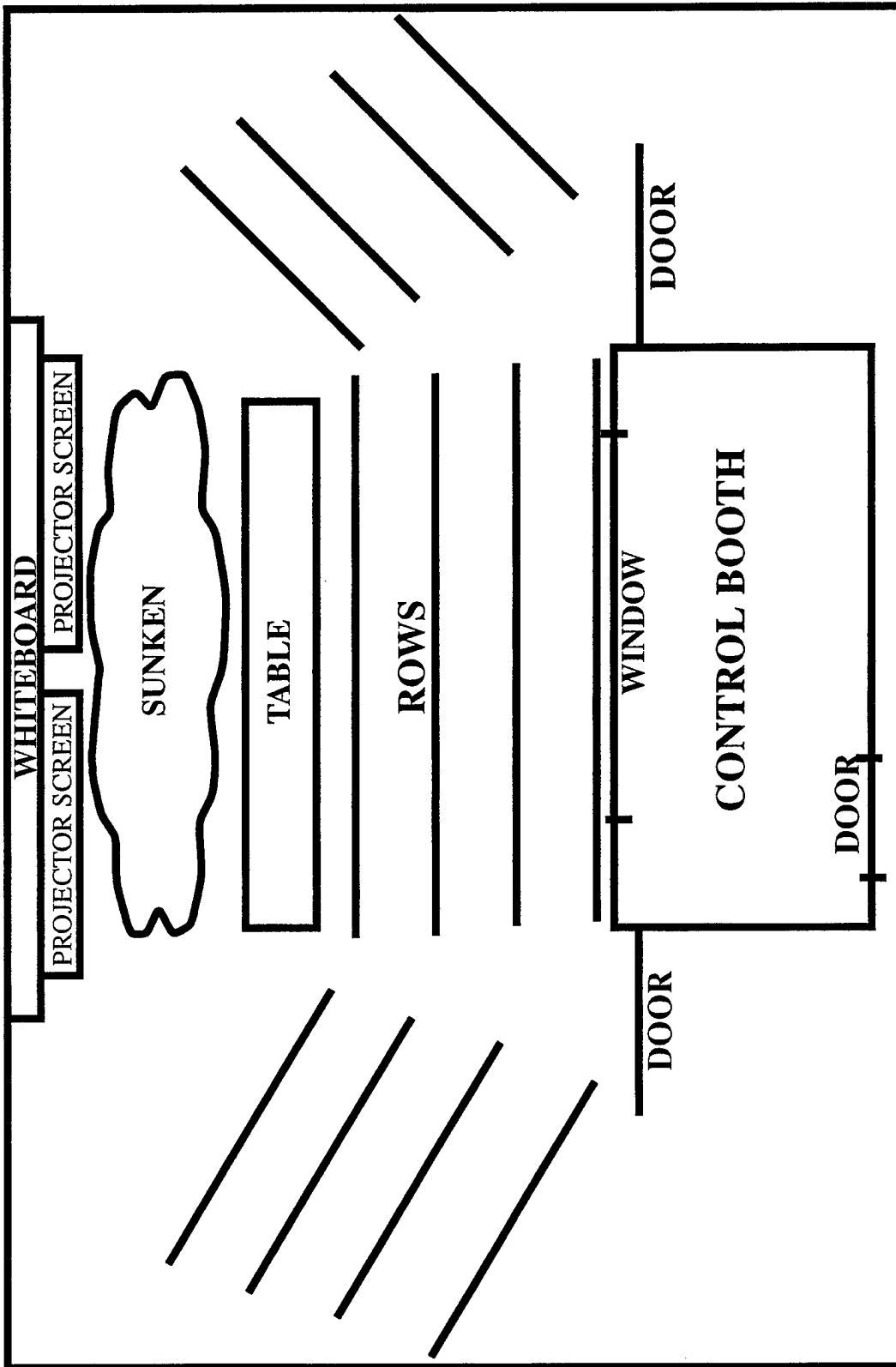


Figure 7.13. NPS Mechanical Engineering Auditorium Amphitheater

- *What are the plans for recording the conference?*

We used a single video camera located in the control booth. Recording from the booth has two problems. There was a window and we had to take picture through that glass window. Sometimes, the monitor screen's reflection or light from outside the booth could appear on the video. The second problem is an inability to videotape audience participations. Camera operators had to be careful to deal with this problem. Since there was no house sound system in the auditorium, a major flaw in the design of the auditorium, we used two wireless microphones. One was attached to the speaker, and the other one was a hand microphone passed to audience members who wanted to ask a question or speak. Since two microphones on the same channel interfered each other, we separated microphone channels, and selected the active microphone by changing the channel number on the receiver unit manually. This is not the proper way of controlling audio, since there was some latency. Latency caused pauses in the sound multicasted through the MBone. A proper mixed solution is needed.

### **3. Software**

MBone tools and network monitoring tools must be installed locally on the computers used in the auditorium.

### **4. Topology**

The configuration of the auditorium for the workshop is shown in Figure 7.14. The VCR and the projector were located in the second row. The reason for this is that, when the projector was on the stage the picture on the screen was very small.

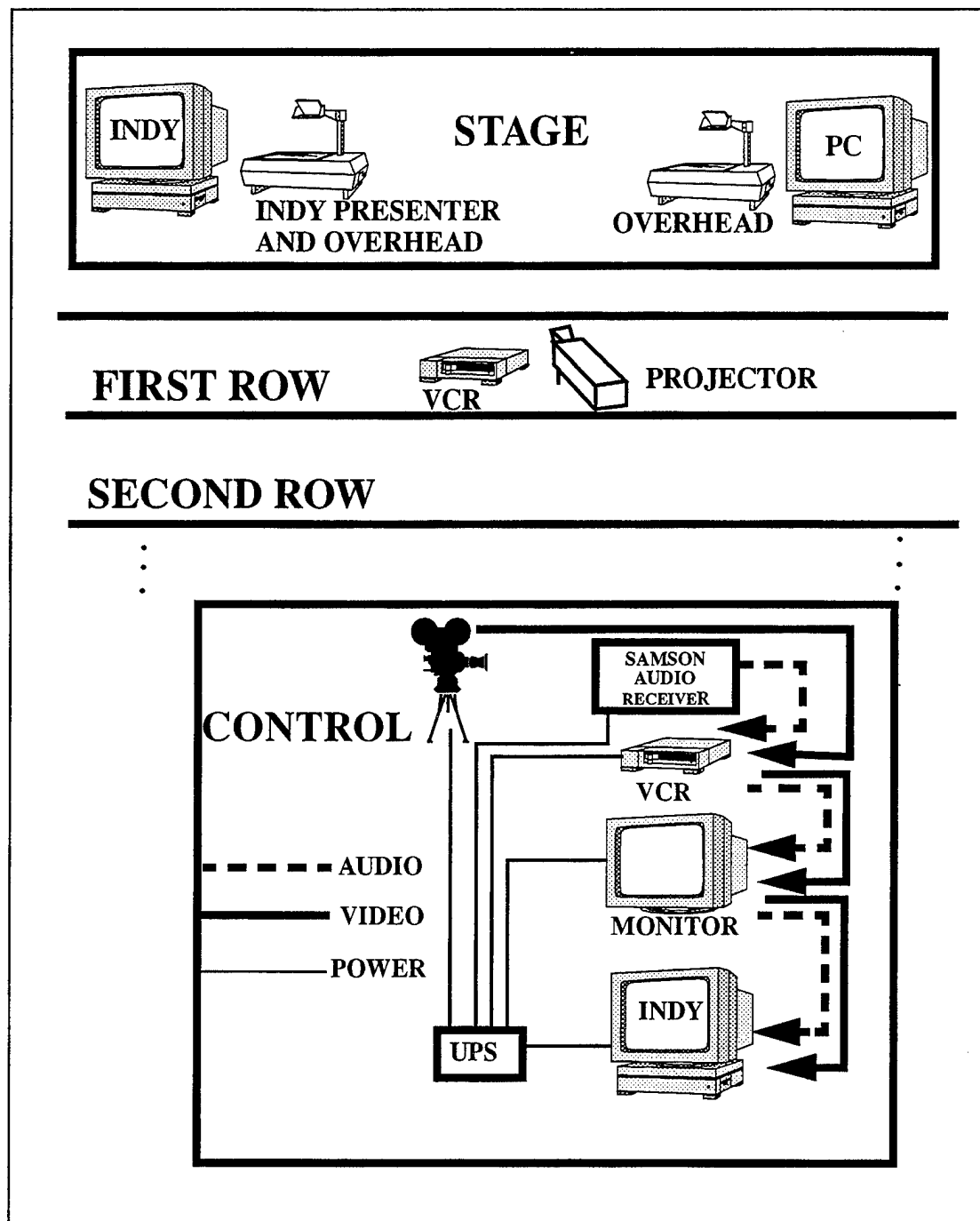


Figure 7.14. Configuration of the Auditorium and the Control Booth

When the projector was in the back of the auditorium, a cabling problem occurred between the VCR and the projector. We could not put the VCR together with the projector at the back of the auditorium, since the speakers would not be able to use the VCR.

Improved auditorium sound design might fix this problem.

## **5. Results**

Web Content and Access Workshop was another experiment for using MBone in distance learning. The primary point in this event was to test digital recording. The most important problem we encountered during the workshop was the audio problem. Since there was no house sound system in the auditorium (which is unusual) we had to use two wireless microphones. Because they interfered with each other when they were on the same channel, we used two different channels. As a consequence, when we switched the channels between the speaker mike and audience mike, there were unnecessary pauses in the multicast. When the speaker and the audience talked on a subject, switching the channels back and forth decreased the audio quality of the multicast. This is an important problem to be corrected. Documentation of this event will allow more professional use of the auditorium in the future for distance learning.

## **E. SUMMARY**

This chapter covered the experiments on using MBone for distance learning purposes. Section B documented the MBone/Web classroom, explaining the issues that should be taken into account in the planning and implementation phases of the classroom experiments. Section C covered the AUV 96 Conference held by NPS between 2-6 June 1996 describing the difference between a conference hall configuration and an MBone classroom, and providing important steps to manage an MBone session in a conference and configuration of a conference hall. Section D examined the same issues for the Web Content and Access workshop that was held on 23 and 26 August 1996 in Mechanical Engineering Auditorium at NPS.



## **VIII. CONCLUSIONS AND RECOMMENDATIONS**

### **A. CONCLUSIONS**

There are two results of this study. One is that MBone can be used for distance learning purposes successfully despite today's limited (128 Kbps) bandwidth reserved for MBone. This has been demonstrated by the MBone classroom, AUV 96 conference and the Monterey Bay Web Content and Access Workshop. The quality of the MBone sessions are nearly at the same level with proprietary commercial distance learning systems. Certainly, there is more work needed to achieve full-motion video with MBone. Nevertheless, we can say that MBone can be used for distance learning purposes today and tomorrow.

The other result is that an MBone classroom costs half as much as a Video TeleConferencing (VTC) room if a workstation is used, and costs one fifth as much as a VTC room if a PC is used. This price comparison may become even more favorable when considering that schools have most of the equipment needed for MBone already in their inventory. In such cases the cost will be even less. Hence, most schools can afford distance learning even though they can't afford VTC rooms. Appendix G provides price comparisons.

### **B. RECOMMENDATIONS FOR FUTURE WORK**

Future improvements on use of 3D graphics, high-bandwidth networks, such as ATM, will be beneficial to over distance learning. 3D graphics has already been included in World Wide Web. Real-time virtual environments using MBone will be another way of utilizing MBone. NPSNET shows the path for doing this. So instead of multicasting video/audio signal, PDUs will travel through the MBone and players will be in the same

virtual environment either for a simulation or for a scientific visualization. ATM may provide a higher-bandwidth network environment for these works. Taking these improvements into account, recommendations for future work may be as follows:

- Distance learning applications of MBone/Web classrooms must be used more often and more classrooms must be built. This does not mean that it is necessary to replace VTC rooms with MBone classrooms, or stop investing in VTC rooms. These two types of classrooms have similar purposes but are not identical. Funding new MBone classrooms ought to be included in the future business plans at the schools. Adding MBone support to existing VTC classrooms may provide the best of both worlds.

- Using MBone with virtual environments needs to be experimented with more seriously. This will be a strong emphasis in next generation distributed networks. There are many important applications in virtual environments. In particular, more research must be done combining virtual environments with video/audio tools and MBone. MBone must be used together with 3D graphics applications.

- Multicast ATM, ATM WAN, and ATM LAN applications need further work. There are many problems but the promise of ATM in support of internetworking remains strong.

- An interesting application of Web/MBone classrooms might be to employ language interpreters on multiple audio channels with multilingual versions of home pages.

## APPENDIX A. CONFIGURING COMPUTERS FOR A NEW SUBNET

When the computers change their subnets for any reason, they have to be assigned new IP numbers in the subnet. Once receiving the new IP number for a computer, this change must be done in the new subnet. It is usually done by changing `/etc/hosts` file, where all IP numbers and symbolic names are stored.

The `/etc/hosts` file is the oldest and simplest way to map names to IP addresses. Each line starts with an IP address and continues with the various symbolic names by which that address is known. A major disadvantage of the `/etc/hosts` file is that the data it contains must be replicated on every machine that wants to use symbolic names. Therefore, various schemes that allow a single version of the hosts file to be kept in a control location are used in networks.

The Domain Name System (DNS) is one of these schemes. DNS uses Berkeley Internet Name Domain (BIND) system. BIND is a program that is usually included in all new UNIX versions. This server runs a daemon called “named.” Different operating systems have different file names in DNS. However, generally there are two resolution files for hosts. One is for resolution from IP address to symbolic name and the other is from symbolic name to IP address. In our subnet, they were “`adrs.63`” for IP-to-name, and “`hosts.stl`” for name-to-IP. These and other mapping files are located under `/etc/` domain.

For adding new computers to a subnet, their `/etc/resolv.conf` file must be corrected according to the new domain name server. We will talk more about this file later. On the server side, the two address resolution files mentioned above must be corrected to include the IP addresses and symbolic names of the new computers. The important thing is to

change the serial number of these files after making a correction. The serial number is basically a date group for the last effective change. The subsequent process for DNS change is to re-activate the system by writing “kill -HUP ‘cat /etc/named.pid’”(in Sun system) as a command. Again these file configuration and commands are SGI specific. For different computer types, related manuals must be checked.

The other system for sharing hosts files is Sun’s Network Information System (NIS). NIS is not only used for sharing /etc/hosts file but also used for sharing:

/etc/passwd

/etc/group

/etc/networks

/etc/services

/etc/protocols

/etc/aliases

/etc/rpc

/etc/netgroup

In systems using NIS, different update procedures are necessary for connecting to a new network. Most operating systems, such as HP-UX, IRIX, SunOS, OSF/1, BSDI support NIS [Nemeth 95]. In this system, basically the machine asks the server machine for any entries in the above files. If the client machine is moved to a new network, it will not be able to find the NIS server, and will fail in a number of surprising ways. NIS maps (the result of a process of making contents of the files by the server as to be seen through the network) are preprocessed by the ndbm extensible hashing routines to improve the efficiency of lookups. Since ndbm allows only one “key” to be associated with each entry

a system file has to be translated into several NIS maps. For instance, `/etc/passwd` file is translated into two maps called “passwd.byname” and “passwd.byuid”. The former is used to look up entries by user name, and the latter to look up entries by UID (User ID) [Nemeth 95].

First thing to do with the computers that changes subnet is to correct `/var/yp/ypdomain` file that has NIS domain name. The new domain name must be written in that file. As a second step, `/etc/hosts` file of the NIS server must be corrected to include new computers' IP addresses and names. It is also necessary to tell the machine just connected to the network where to send packets for routing. For SGI machines, we changed `/etc/rc2.d/S31network` file to show the default route when the computer does not know what to do. In the `/etc/resolv.conf`, we should order the systems that the host machine will look at to include NIS. Now we have both DNS and NIS in our “resolv.conf” file. For IRIX operating system used in SGI machine, “hostresorder” magic word is used to make an order of the systems that will be checked when an IP address, or other sorts of files needed by the client. When we write “hostresorder nis bind local” this means, first check nis, then bind and then local files. If we want to include `/etc/passwd` file into NIS password map, we need to put a plus “+” sign in a line under the users passwords in that file. The last step with NIS is to re-activate NIS by running “ypmake” command at the server.

However, if you choose the easiest way and use your local files, then the process gets simpler. In this case:

- Change your computer's name in `etc/sys_id` with the new one.
- Change `/etc/resolv.conf` to appear as:  
“hostresorder local bind nis  
domainserver your new Domain Server”
- Turn off NIS by changing `/etc/config/yp` content to “off”.
- Add computer's new name and domain to `/etc/hosts` file.

- Add new gateway address to `/etc/rc2.d/S31network` file by adding “route add net default ‘gateway address’ threshold (usually 1)”

If the last one does not work for some reason and you cannot connect to anywhere, then try to write the same sentence in the command line. This may work until you reboot the computer.

This is just a network connection part of a new configuration. We also need to use mail, telnet, ftp, printer utilities etc. in the new network. These are made by mounting these programs to NFS (Network File System). That system basically allow the computers share files in the network. I will not go in to details of NFS configuration, because this goes beyond the limits of this appendix. One important issue is that, you should make sure the `/usr/local/bin` files match up. Typically you will have `/usr/local/bin` NFS mounted in the old network. When you move, all the `/usr/local/bin` programs will go away. You need to back up the appropriate files that are installed, such as MBone tools, Web browsers etc., with the correct version, usually under `/usr/local` directory on the local disk.

## APPENDIX B. MBONE RELATED INFORMATION

This appendix contains useful information about important aspects of MBone, including mailing lists, kernel and mrouted software download sites, MBone desktop application sites, and MBone related information sites respectively.

### *MBone mailing lists:*

The followings are the participating networks' e-mail addresses

AlterNet	ops@uunet.uu.net
CERFnet	mbone@cerf.net
CICNet	mbone@cic.net
CONCERT	mbone@concert.net
Cornell	swb@nr-tech.cit.cornell.edu
JANET	mbone-admin@noc.ulcc.ac.uk
JvNCnet	multicast@jvnc.net
Los Nettos	prue@isi.edu
NCAR	mbone@ncar.ucar.edu
NCSAnet	mbone@cic.net
NEARnet	nearnet-eng@nic.near.net
OARnet	oarnet-mbone@oar.net
PSCnet	pscnet-admin@psc.edu
PSInet	mbone@nisc.psi.net
SESQUINET	sesqui-tech@sesqui.net
SDSCnet	mbone@sdsc.edu
SURAnet	mbone@sdsc.edu
UNINETT	mbone-no@uninett.no

MBone request addresses for your region to be added to MBone mailing lists for purposes of coordinating setup of tunnels, etc:

mbone-eu:	mbone-eu-request@sics.se	Europe
mbone-jp:	mbone-jp-request@wide.ad.jp	Japan
mbone-korea:	mbone-korea-request@cosmos.kaist.ac.kr	Korea
mbone-ca:	canet-mbone-request@canet.ca	Canada
mbone-na:	mbone-na-request@isi.edu	North America
mbone-oz:	mbone-oz-request@internode.com.au	Australia
mbone-sg:	mbone-sg-request@lincoln.technet.sg	Singapore
mbone-uk:	mbone-uk-request@cs.ucl.ac.uk	UK
mbone:	mbone-request@isi.edu	other

These lists are primarily aimed at network providers who would be the top level of the MBONE organizational and topological hierarchy. The mailing list is also a hierarchy; mbone@isi.edu forwards to the regional lists, then those lists include expanders for network providers and other institutions. Mail of general interest should be sent mbone@isi.edu, while regional topology questions should be sent to the appropriate regional list.

For all Remote Conferencing related issues, subscribe to:  
rem-conf-request@es.net

For all Conference Control related issues, subscribe to:  
confctrl-request@isi.edu

For Radio multicasts on MBone, subscribe to:  
vat-radio-request@elxr.jpl.nasa.gov

For RSVP discussions, subscribe to:  
rsvp-request@isi.edu

For Integrated Services issues, subscribe to:  
int-serv-request@isi.edu

***MBone kernel and mrouted software download sites:***

Version 3.8 of Mrouted and Version 3.5 of IP multicast OS kernel extensions are available at the following sites.

For all platforms, <http://www.merit.edu/net-research/mbone/index/platform.html>  
For SGI, <ftp://ftp.sgi.com>  
For Solaris, <ftp://ftp.uoregon.edu>, and <ftp://playground.sun.com>  
For DEC-Alpha running OSF1 V2.0, <ftp://chocolate.pa.dec.com>  
For FreeBSD 2.1/NetBSD, <ftp://ftp.parc.xerox.com>  
For HP/UX 9.05, <ftp://ftp.parc.xerox.com>



***MBone desktop application software download sites:***

For all platforms

<http://www.merit.edu/net-research/mbone/index/platform.html>

For the Unix OS platform:

Audio Conference Tool (VAT 4.0):

[ftp://ftp.ee.lbl.gov/conferencing/vat/alpha-test/vat-4.0\\*](ftp://ftp.ee.lbl.gov/conferencing/vat/alpha-test/vat-4.0*)

Audio Conference Tool (Nevot):

<ftp://gaia.cs.umass.edu/pub/hgschulz/nevot>

Video Conference Tool (NetVideo):

[ftp://parcftp.xerox.com/pub/net-research/nvbin-3.3\\*](ftp://parcftp.xerox.com/pub/net-research/nvbin-3.3*)

Video Conference Tool (IVS):

[ftp://zenon.inria.fr/ivs/rodeo/ivs/version3.3m3/ivs3.3m3-\\*](ftp://zenon.inria.fr/ivs/rodeo/ivs/version3.3m3/ivs3.3m3-*)

Video Conference Tool (Vic 2.7):

[ftp://ftp.ee.lbl.gov/conferencing/vic/alpha-test/\\*-vicbin-2.7.\\*](ftp://ftp.ee.lbl.gov/conferencing/vic/alpha-test/*-vicbin-2.7.*)

Shared WhiteBoard Tool (wb):

[ftp://ftp.ee.lbl.gov/conferencing/wb/wb-1.57\\*](ftp://ftp.ee.lbl.gov/conferencing/wb/wb-1.57*)

IMM (JPEG Images):

[ftp://ftp.hawaii.edu/paccomm/imm-3.3/imm-\\*](ftp://ftp.hawaii.edu/paccomm/imm-3.3/imm-*)

Shared Mosaic

<ftp://ftp.eit.com>

Session Directory Rendezvous Tool (sd):

[ftp://ftp.ee.lbl.gov/conferencing/sd/sd-1.13\\*](ftp://ftp.ee.lbl.gov/conferencing/sd/sd-1.13*)

SDR

<ftp://ftp.parc.xerox.com/pub/net-research/apps/sdr>

MMCC Rendezvous Software:

<ftp://ftp.isi.edu/confctrl/mmcc/>

MBone applications for the Macintosh

Video Conference Tool (Cu-SeeMe) (no multicast support)

[ftp://gated.cornell.edu/pub/video/Mac.CU-SeeMe\\*](ftp://gated.cornell.edu/pub/video/Mac.CU-SeeMe*)

Maven Audioconferencing Tool (no multicast support)  
*ftp://k12.cnidr.org/pub/Mac/Dir-Soundstuff/Maven-\*.sea.bin* (MacBinary)

MBone applications for PC/Windows

Video Conference Tool (Cu-SeeMe) (no multicast support)  
*ftp://gated.cornell.edu/pub/video/PC.CU-SeeMe\**

Vic, Vat, Nv, and Sdr  
*ftp://ftp.ee.lbl.gov/conferencing*

Sd, Vat, Nv  
*ftp://ftp.nus.sg/pub/zl/EE/MBONE*

***MBone related information sites:***

The JIPS MBONE Page in England  
*http://www.cl.cam.ac.uk/mbone/*

RIPE MBone WG Page  
*http://www.it.kth.se/~e93\_mda/mbone/ripegw/*

The AT&T MBONE Page  
*http://www.research.att.com/mbone-faq.html*

MBone/IP Multicast Tools  
*ftp://agate.lut.ac.uk/pub/mbone/*

Naval PostGraduate School MBone information page  
*ftp://taurus.cs.nps.navy.mil/pub/mosaic/nps\_mosaic.html*

Geneva University MBone page  
*http://www.unige.ch/seinf/mbone.html*

NLM MBone Page  
*http://www.nlm.nih.gov/reports.dir/multicasting.dir/DOCS.dir/multicast\_details.html*

Digital MBone Page  
*http://chocolate.pa.dec.com/mbone*

SigNet Home Page  
*http://www.acm.uiuc.edu/signet/*

## APPENDIX C. ABBREVIATIONS

AAL	ATM Adaptation Layer
ARPA	Advanced Research Project Agency
ATM	Asynchronous Transfer Mode
ATMARP	ATM Address Resolution Protocol
AUV	Autonomous Underwater Vehicle
BAGNET	Bay Area Gigabit Testbed NETWORK
BAYNET	Bay Area Network
BBS	Bulletin Board Systems
BIND	Berkeley Internet Name Domain
CalREN	California Research and Education Network
CANARIE	Canadian Network for the Advancement of Research, Industry and Education
CBone	Cyberspace Backbone
CBR	Constant Bit Rate
CBVE	Chesapeake Bay Virtual Ecosystem Model
CCITT	Consultative Committee on International Telephone and Telegraph-Now ITU
CGF	Computer Generated Forces
CLP	Cell Loss Priority
CRC	Cyclic Redundancy Control
CS	Convergence Sublayer
CSUMB	California State University Monterey Bay
DIS	Distributed Interactive Simulations
DNS	Domain Name System
DS-n	Digital Signal level n
ESPDU	Entity State PDU
GFC	Generic Flow Control
HTTP	Hypertext Transfer Protocol
IETF	Internet Engineering Task Force
IGMP	Internet Gateway Message Protocol
IP	Internetworking Protocol
ITU	International Telecommunications Union
I-WAY	International Wide-Area Year
LAN	Local-Area Network
LIS	Logical IP Subnetwork
LSVE	Large-Scale Virtual Environment
MARS	Multicast Address Resolution Server
MBA	Monterey Bay Aquarium
MBARI	Monterey Bay Aquarium Research Institute
MBone	Multicast Backbone
MICE	Multimedia Integrated Conferencing for European Researchers
MOSPF	The Multicast Extensions to Open Shortest Path First
mrouter	multicast router
NBMA	Non-Broadcast Multi-Access

NFS	Network File System
NHRP	Next Hop Resolution Protocol
NHS	NHRP Server
NIC	Network Interface Card
NIS	Network Information System
NNI	Network-to-Network Interface
NPS	Naval Postgraduate School
NPSNET	NPS Network
NSA	National Security Agency
NTON	National Transparent Optical Network
nv	Network Video
OC-n	Optical Carrier level n
OCRInet	Ottawa Carleton Research Institute net
PBX	Private Branch eXchange
PDU	Protocol Data Unit
PT	Payload Type
PVC	Permanent Virtual Circuit
ROLC	Routing Over Large Clouds
SAF	Semi-Automated Forces
SAR	Segmentation And Reassembly
SDH	Synchronous Digital Hierarchy
SEAL	Simple and Efficient Adaptation Layer
SIMNET	SIMulator NETworking
SONET	Synchronous Optical NETwork
STL	System Technology Lab
STRICOM	Simulation Training and Instrumentation Command
STS-n	Synchronous Transport Signal level n
SVC	Switched Virtual Circuit
UCSC	University of California, Santa Cruz
UID	User ID
UNI	User-to-Network Interfaces
UPS	Uninterruptable Power Supply
VBR	Variable Bit Rate
VCI	Virtual Circuit Identifier
VPI	Virtual Path Identifier
VRML	Virtual Reality Modeling Language
vrtp	virtual reality transfer protocol
VTC	Video Tele Conferencing
WAN	Wide-Area Network
WWW	World Wide Web

## APPENDIX D. ON-LINE AVAILABILITY OF THESIS PRODUCTS

Postscript and html formats of this thesis are available at

*<http://www.stl.nps.navy.mil/~iirg/tamer/thesis.html>.*



## **APPENDIX E. BUILDING AND RUNNING MBONE/WEB CLASSROOM**

This appendix documents the connection configuration of an MBone/Web classroom from a more technical and detailed perspective. The first part is the configuration part and the second part is a user reference to run the classroom and necessary MBone tools.

The ways to determine the hardware requirements and hardware, software, and topology are explained in Chapter IV and Chapter VII respectively. In this part, the author documents necessary information for those who want to get an MBone/Web classroom working in their school. Audio/video connections of the MBone/Web classroom are shown in Figure E.1.

### **1. How to make connections in the classroom.**

#### ***a. Connect the wireless microphone to the video camera.***

Wireless microphones are made of two separate parts. One is the receiver part, and the other is the transmitter part. On the video cameras, there is usually a jack for external microphones. Connect one end of your wireless microphone cable into this jack. Plug the other end of the cable to the “audio output” jack on the receiver part of the wireless microphone (don’t turn on anything yet!). Plug the antenna into the “antenna” jack. You will see the necessary information about the other part of the wireless microphone set later on.

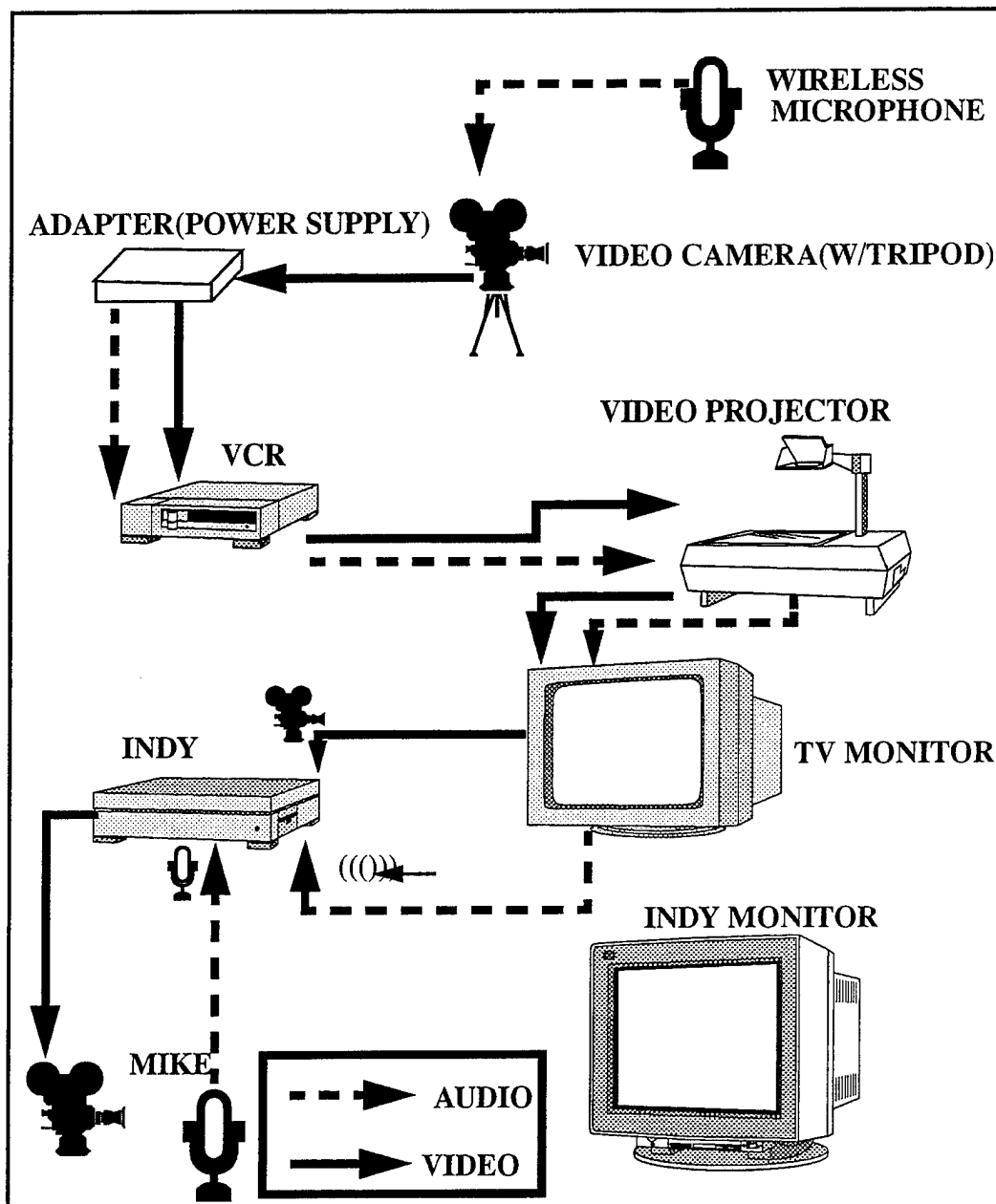


Figure E.1 MBone Classroom Connections

*b. After putting your video camera over the tripod, you should plug the power adapter's cable into the camera.*

Take the cables and connect them into the adapter's back panel according to the Figure E.2. If you need connectors for different types of cable (you usually do,



because it changes from camera to camera) provide these connectors. Put a blank tape into the camera and set the “normal” or “record” position on the camera. This does not necessarily mean that you should start recording. There is usually a record selector on the cameras. This is important because otherwise you can not use the wireless microphone at all.

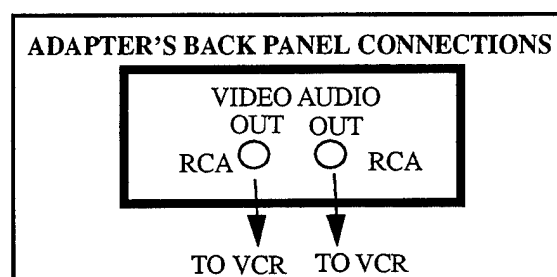


Figure E.2 Video Camera Power Adapter's Back Panel

*c. Make the connections in the vcr's back panel according to Figure E.3.*

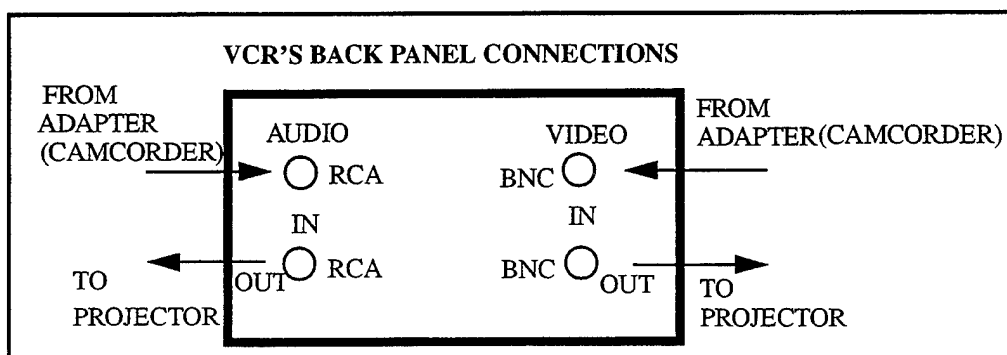


Figure E.3 VCR's Back Panel Connections

*d. Make the connections in the projector's back panel according to*

*Figure E.4.*

I have used “video in 1” part on the back panel.

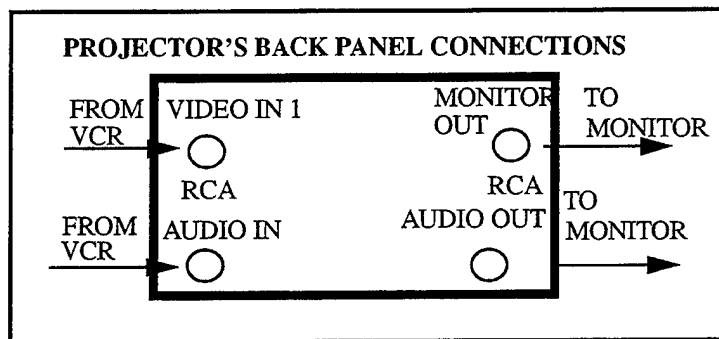


Figure E.4 Projector's Back Panel Connections

*e. Make the connections in the TV monitor's back panel according to*

*Figure E.5.*

I have used "line A" part on the back panel.

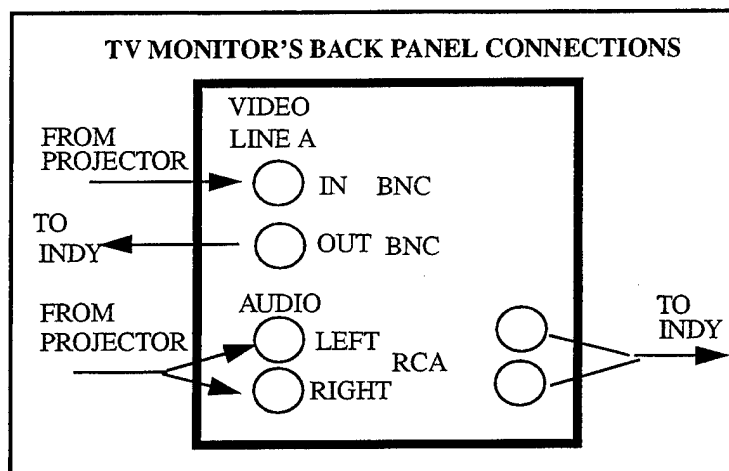


Figure E.5 TV Monitor's Back Panel Connections

*f. Make the connections in Indy's back panel according to Figure E.6.*

Indys have only video input and no video output. So this issue must be taken into consideration when making these kind of configurations. I assume that you have an installed Indy camera in the system.

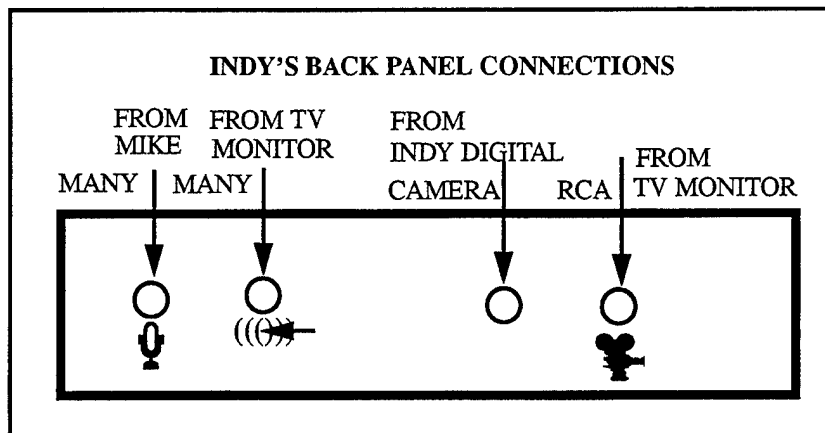


Figure E.6 Indy's Back Panel Connections

*g. Now plug all the power cords of the equipment, turn them on.*

You should turn all of them on to have the system working.

*h. Turn on the receiver part of the wireless microphone.*

You should turn the volume knob to the right, and hear a "click" sound.

Also you should check the battery lamp. To turn on the transmitter part of wireless microphone, you should slide the button on this part to the opposite side of "off." You will need 1-2 sets of batteries per day of use.

## 2. How to work with the MBone tools

*a. Login to the computer if it is not already logged in.*

*b. In the unix shell window, write "sdr" to run the MBone application program.*

*c. You should see a window that shows all the MBone sessions*

*(Figure E.7).*

If you want to join one of them, just double click on the session, then skip to step g.



Figure E.7 Session Directory Window.

*d. If you need to create a new session, click the “New” button.*

*e. On the “Create” window (Figure E.8) you will see ,*

Fill the name of the “Session Name” and the “Description” parts by writing a name and a short description of the session. Click “video” button and choose the video software by clicking and choosing one under “Format” column. Make sure that in the “Scope” part, “Site” is highlighted unless you are sure that you want to make a regional or global Mbone session. When you are finished click the “Create” button to create the new session.

*f. Return to step c and follow the instructions.*

*g. When the session is opened, you should see a “Session Information” window (Figure E.9).*

**Create New Session**

Session Name: test session for Mbone classroom

Description:  
Test session for Mbone Classroom

URI:  Test URI

<b>Security:</b> <input checked="" type="radio"/> Public <input type="radio"/> Private	<b>Type of Session:</b> Test <b>Scope Mechanism:</b> <input type="radio"/> TTL Scope <input checked="" type="radio"/> Admin Scope	<b>Scope:</b> Site (tu 15) Region (tu 63) World (tu 127)
--	---	---

Media:	Protocol	Format	Address	Port
<input checked="" type="checkbox"/> audio	RTP	PCM	224.2.211.42	29098
<input checked="" type="checkbox"/> video	RTP	H.261	224.2.247.2	60468
<input type="checkbox"/> whiteboard				
<input type="checkbox"/> text				

**Session will be active:**

Once from: Mon 9 Sep \* at 21:00 \* for 2 hours \*

--- from: \* at \* for \*

--- from: \* at \* for \*

Repeat for: \*

**Contact details:**

☐ Murat Tamer mttamer@nps.navy.mil

☐ Don Brutman 408.656.2149

Create Show Calendar Help Dismiss

Figure E.8. Create New Session Window in *Sdr*

*h. When you click “Start All” button in Figure E.9, you should see two different windows.*

One is video tool window (“vic” in our example), and the other is “Select a tool” window (Figure E.10). Click the “vat” or “rat” button (“vat” in our example) on the

window. When you click “Start tool” button you will see “visual audio tool” (vat) window (Figure E.11). Click the “menu” button on the window. You should click on the “full duplex” at the upper part of the window (Figure E.12). Then “dismiss” the window.

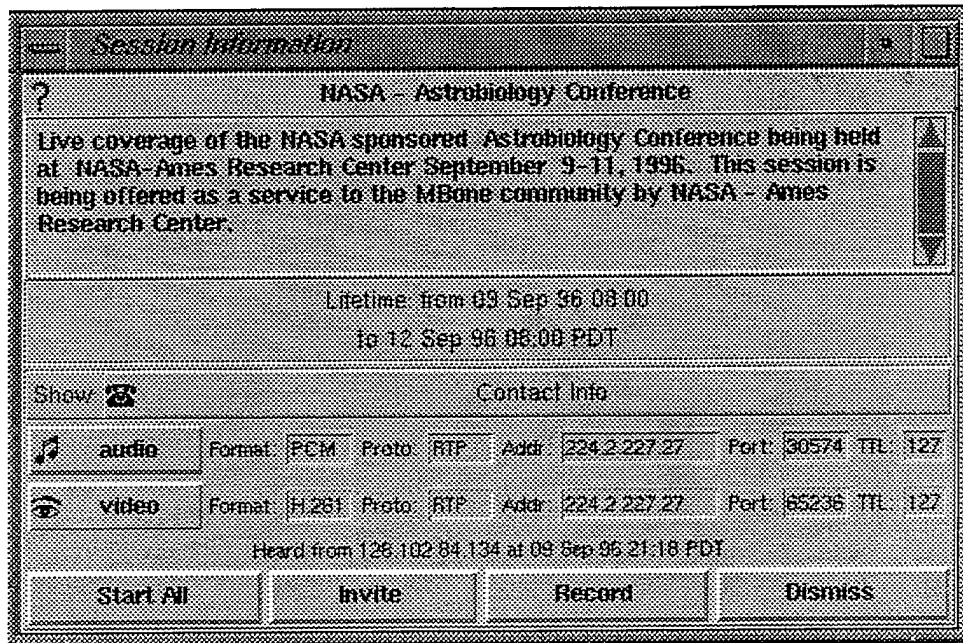


Figure E.9. Session Information Window



Figure E.10. Select a Tool Window.

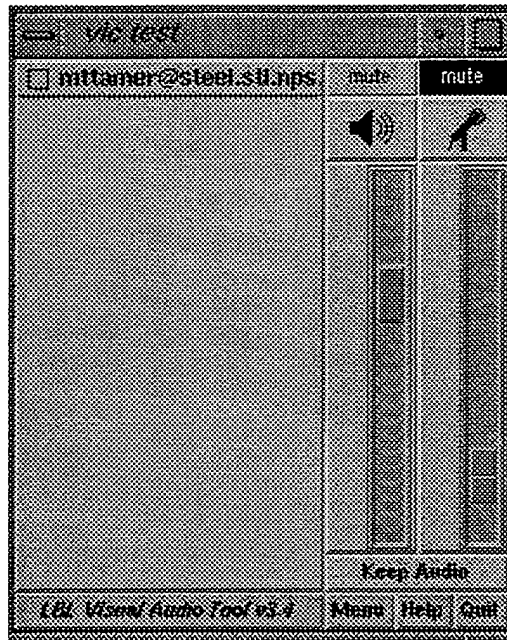


Figure E.11. Visual Audio Tool (vat) Window.

*i. You can switch the microphones from “mike” button on the visual audio control panel (Figure E.13).*

Also you should click on the “talk” above the “mike” button to use full duplex mode which means you can send and hear at the same time.

*j. Click on the “menu” on the “vic” window (Figure E.14).*

*k. Choose the camera you will use by clicking the “port” button at the middle of the window (Figure E.15), and selecting the “digital” for Indy camera, or “analog” for video camera.*

*l. Click on the “transmit” button at the top of the window to send your picture to the network.*

Audio Tests		Priority
<input type="radio"/> none	<input type="radio"/> -6dBm tone	<input type="radio"/> high (200)
<input type="radio"/> loopback	<input type="radio"/> 0dBm tone	<input type="radio"/> med (100)
	<input type="radio"/> max tone	<input type="radio"/> low (10)
		<input type="radio"/> 100

Output Mode	
<b>Spkr</b>	
<input type="radio"/> Mike mutes net	
<input type="radio"/> Net mutes mike	
<input type="radio"/> Full duplex	
<input type="checkbox"/> Autoraise	<input type="checkbox"/> Keep All Sites
<input type="checkbox"/> Disable Meters	<input type="checkbox"/> Mute New Sites
<input type="checkbox"/> No Silence Suppr	

Automatic Gain Control	
<input type="checkbox"/> Spkr	0 dB
<input type="checkbox"/> Mike	0 dB

Network		
<input type="radio"/> Conference	<input type="radio"/> PCM	<input type="radio"/> DV1
<input type="radio"/> Lecture	<input type="radio"/> PCM2	<input type="radio"/> DV12
	<input type="radio"/> PCM4	<input type="radio"/> DV13
		<input type="radio"/> GSM
		<input type="radio"/> LPC4

Dest: 224.2.131.29 Port: 47641 ID: 30537 TTL: 16

Name: mltamer@steal.stnaps.navy.mil

Title: vic test

☐ Key:

**Dismiss**

Figure E.12. Vat Menu Window.



Figure E.13. Microphone Button on Vat Window.



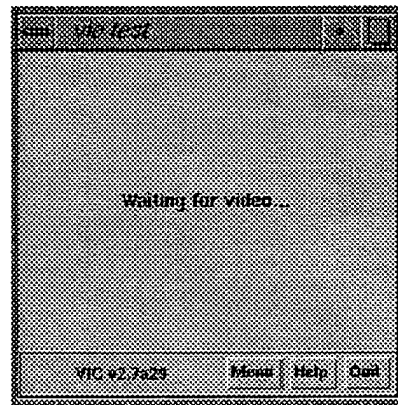


Figure E.14. Vic Window.

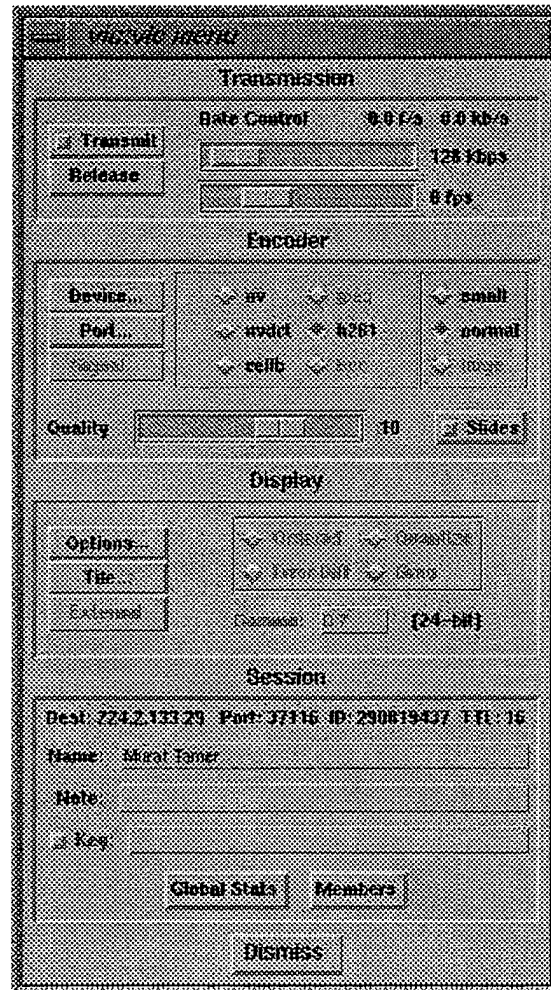


Figure E.15. Vic Menu Window.

*m. You should see near end picture on the “vic” window (Figure E.16).*

If you click on the picture, you can enlarge the picture.

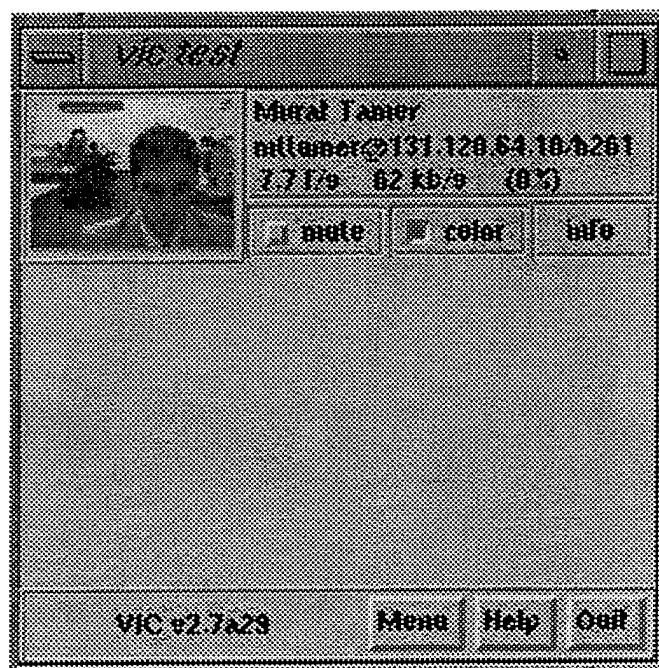


Figure E.16. Near End Picture in Vic Window.

### **3. How to operate in a built and connected classroom**

*a. Turn on the computer, external hddisk, TV monitor, video camera,*

Put a blank tape in it. Make sure that “rec” led is on. Otherwise push the “rec” button on the panel. This “rec” is not the same as “record” button which is red and let the camera record. Remove the cap from the lens.

*b. Turn on the receiver part of the wireless microphone.*

Turn up the volume control to the right. Make sure the red led is turned on, and “low bat” led is off.

*c. Turn on the transmitter part of the wireless microphone.*

Slide the “xmtr off” button to the right and keep the other button on

“audio”. Make sure the red led is turned on, and “low bat” led is off.

*d. TV monitor must be showing “LINE A” on its front panel.*

*e. Now all the equipment should be turned on, and you should see what the camera is recording on the tv monitor.*



## **APPENDIX F. PLANNING AND MANAGING A MULTICAST SESSION FOR AUV 96 CONFERENCE**

This appendix documents what was done in the planning and during the AUV 96 conference. The first part examines the preparation for the conference, determination of the requirements both for equipment and for people. The second part describes the hardware/software configuration for the conference and lessons learned.

### **1. Preparation for the Conference**

It is always good to make a list first of what is needed in the conference. This list should include both the equipment and the people. Two weeks prior to the conference, a conference room walk-through must be done to become familiar with the location where the equipment will be setup. This is especially important for final configuration issues, since what is expected is not always the same as what people prepare or have in the conference room. After the walk-through and discussions with the people in charge of the conference rooms, a final configuration can be made.

The last step prior to the conference is to test all the equipment that will be used in the conference with its final hardware/software configuration. This testing permits effective troubleshooting and dramatically decreases the time spent for the same purpose during the conference. Testing the equipment may reveal some additional missed points. In AUV 96, we used two Airlan wireless bridges to connect conference rooms to one of the subnets in NPS. Therefore it was a good idea to test the bridges before the conference but in the same location as they would be used in the conference. The bridges were the most important part of the job. If they didn't work, nothing could be done with MBone, since there were no network connections in the conference room.

Two or three days before the conference, all the equipment was packed and made ready for moving to the hotel. The next day, the equipment was moved to the conference room, all the configurations set as planned, and tests performed. A watch bill is needed for people deployed in the conference. For each session, one person needs to work with the computer (MBone tools), one person needs to operate the video camera (since we had only one video camera) and one person is a substitute either for the computer operator, or for the video camera operator. So three people were used. It is advisable to have two different watches in a day period, since it is not so easy to stay there for eight hours and be fully alert and cautious.

Equipment requirements for AUV 96 conference were as follows:

- Two Indy workstations, with at least one presenter. Presenter is very useful if the speaker from your school wants to show a home page or anything using a Web browser.
- One PC with Mbone tools and network tools installed (win95).
- One UPS (not a small one, it can support at least 6-8 plugs).
- One video camera (this may change depending on the configuration you made).
- Two VCRs (one is used by the speakers, the other is used by you. It is good to have at least one SVHS VCR, since it has more input and output jacks than regular ones).
- Two TV monitors, one big screen and one small screen like 13". The big one is useful either for the cameraman to see what he/she is shooting, or audiences to see the speaker closer, and watch the video tape that the speaker plays. The small one is necessary on the computer desk to see what the video is recording and what you are multicasting. The number of TV monitors also increases when the number of video cameras increases.
- One tripod (it is one for each video camera).

- One video projector for the VCR that is used by speakers.
- One prerecorded test video tape to see if the configuration related to VCR is working.
- One pair of walky-talkies or cellular phones (at least), this is extremely important, when you are testing or working with the wireless bridges, on the roof. You need to talk to the people down in the conference center to verify that the network is working.
- One cellular phone to get in touch with the school for the network confirmation again.
- One wireless mike as a backup for house sound system and spare batteries.
- One head phone to listen to the sound you are transmitting from MBone. This is also important since usually, you may disturb audiences if you try to listen to the sound directly from the monitor.
- A long Ethernet cable and connection tools to make your own Ethernet connections as you wish.
- Three or four power strips to make use of a limited number of power outlets for your large numbers of equipment.
- Blank video tapes, labels etc.

## **2. Conference Period**

With the requirements above, the connection schema of the conference room is shown in Figure F.1. Antennas used with the wireless bridges are directed antennas, so they need to see each other with correct polarization (means that they need to be

symmetrically aligned, either vertically or horizontally). All the audio is connected to the audio mixer provided by the conference center. The audio was taken from that audio mixer to the SVHS VCR. One good thing about the audio mixer was that it was close to the system. The operator could turn up or turn down the volume of individual microphones, if they interfered with each other. The good thing about the VCR used was that it had two input and two output audio/video jacks. This gave an important flexibility with connections. The microphone stand was placed in the middle of the auditorium. A large TV monitor was used by the cameraman to see what he was shooting since the view finder of the camera was too small to look through for hours. The same monitor was also used by the audiences who were on the far side of the room, to see the speakers, slides, or video tapes better.

### **3. Lessons Learned from the Conference**

Some notes can be listed as follows:

- Speakers should be requested to prepare their slides in a predetermined font and size. Some slides were really impossible to see through MBone, even when maximum zoom was used. Actually these slides couldn't be read by near-end audiences either. Our rule of thumb for slides over the MBone is that good slides look fine and bad slides look worse.

- We originally thought that, in order to multicast a good picture quality we should set the vic quality according to the object that is shot. For instance, if a slide is shot, then we might increase the quality by decreasing the amount down to 1 on the vic menu (Figure F.2).





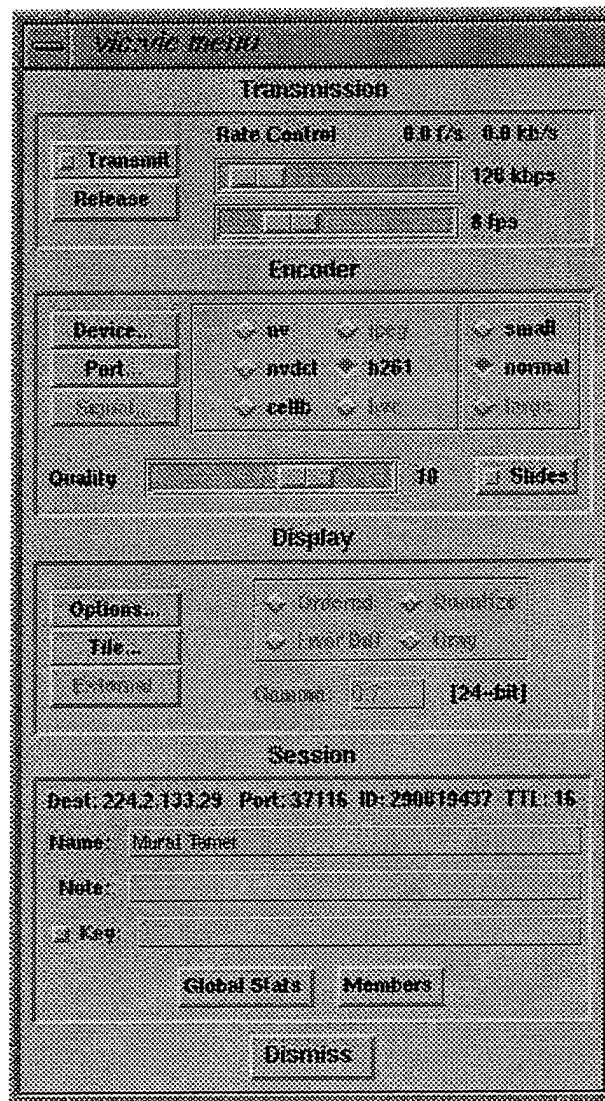


Figure F.2 Vic Menu Window

- There were several problems with the network. These were not usually hardware problems. Since there are many subnets and linked tunnels between these subnets, when a system administrator tries to install a new router, or a daemon, he/she may delete a tunnel or forget to re-run the mrouter daemon. That may cause a variety of problems. Fortunately, we found the network administrator by phone to make the network run properly again in each case. As a consequence, it is a good idea to send e-mails to all system administrators

at the school informing them of session time.

- Labeling all cables and equipment before tearing down when you are finished with the conference can save a lot of time in matching cable to machine later.

- If battery powered equipment is used, then be sure that all the batteries are fully charged and there are also some spares.



## APPENDIX G. PRICE COMPARISON OF MBONE AND VTC

The following information provides a simple price comparison of different types of MBone classrooms with different types and quality of VTC classrooms. One important thing to point is this comparison does not include a quality comparison. Since VTC is a commercial system, its quality is supposed to be higher than the MBone while Web/MBone classroom has greater functionality than VTC classroom due to Web connectivity. Our purpose is to show that the MBone is an effective and affordable system that can be used by any public school, not necessarily to show the highest quality or the most functional one.

The NPS VTC classrooms costs \$45,000 and contains the equipment listed in Figure G.1 [Walsh, 96].

• VTC system	PictureTel 4000.
• PC	For word processing or presentation purposes.
• Imux	Necessary for bandwidth higher than 112Kbps.
• TV Monitor	Three TV monitors are used.
• Fax	Used for documentation transfer to the far end.
• Document camera	Used for viewing slides or PC presentation.
• Polycam	The main camera that is used in the VTC classroom.
• Auxiliary camera	The second camera that is used in the classroom.
• VCR	Two for recording and one for playing.
• NT1	Terminator for ISDN.
• UPS	Uninterrupted Power Supply.
• Auto microphones	Microphones in the classroom.
• Scan convertor	Converts PC image to the digital data for ISDN.

Figure G.1. NPS VTC Classroom Equipment List.

Various configurations of a Web/MBone classroom are shown in Figure G.2.

System ID	Price(\$)	Classroom (Indy)	Classroom (PC)	Receive-only (Minimum PC)
Video Camera	0.5K	X	X	
TV monitor	0.7K	X	X	
Indy (w/presenter)	17K	X		
Pentium (PC)	1.5K		X	X
Digital camera	0.15K			
Video capture card	0.2K		X	
LCD presenter	2K		X	X
VCR	0.2K	X	X	
Wireless microphone	0.15K	X	X	
Overhead projector	0.2K	XX*	XX*	X
Projection screen	0.15K	XX*	XX*	X
	TOTAL	\$19,250**	\$5,950***	\$3,850
* Two of them were used.				
** It costs \$18,750 when digital camera is used instead of video camera.				
*** It costs \$5,600 when digital camera is used instead of video camera.				

Figure G.2. Web/MBone Classroom Equipment and Price List.

It should be noted that Figure G.2 disregards the cost for configuring the classrooms themselves for distance learning purposes, i.e. building special walls or installing directed lights. In our MBone classrooms we didn't pay for these kinds of expenses. For a VTC classroom, it is essential to upgrade the room configuration for adequate audio/video quality. Internet connection charges are separate and likely identical in each case.

The following numbers give the cost ratio of each system being used.

**Web/MBone classroom (SGI Indy)/VTC classroom at NPS: 42%**

**Web/MBone classroom (PC receive)/VTC classroom at NPS: 8%**

Using these ratios, we can say that a Web/MBone classroom using SGI *Indy* can be 42% as expensive as a VTC classroom at NPS, and a Web/MBone classroom using a PC in receive-only mode can be 8% as expensive as a VTC classroom at NPS. Even though there is currently no MBone video tool to transmit from a PC with a video capture card, by assuming there will be in the near future, ratios of a Web/MBone classroom using a PC in with a capture card is as follows:

**Web/MBone classroom (PC transmit)/VTC classroom at NPS:      12%**

Consequently, PC Web/MBone classrooms appear to be affordable for schools.





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